Interim Report

on

The Investigation of the Upper Ottawa Street Landfill Site

by the

Upper Ottawa Street Landfill study Committee

May 31, 1983

INTERIM REPORT

on

THE INVESTIGATION OF THE UPPER OTTAWA STREET LANDFILL SITE

by the

UPPER OTTAWA STREET LANDFILL STUDY COMMITTEE

20 Jackson Street West
Suite 412
Hamilton, Ontario
L8P 1L2
(416) 524-2434

May 31, 1983.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The Committee is nearing completion of the first stage of its investigation. Beginning in the summer of 1981, analytical studies were carried out on air, surface water and groundwater at the landfill and in the surrounding neighbourhoods. This report presents the results that have been obtained from these studies. The second stage of the Committee's work involves conducting health studies of persons working at or near the landfill, and area residents, and will be the subject of a later report.

1. After reviewing available records on the history of dumping at the landfill, the Committee has concluded that the amounts and types of wastes buried in the landfill will never be fully known with any degree of certainty. This situation reinforces the Committee's belief that the landfill must be monitored closely for any changes in the release of pollutants into the surrounding air and water.

Core samples taken from depths of up to 85 feet in two locations on the landfill have been analyzed by Mann Testing Laboratories. As expected, many more chemicals in much higher concentrations are found within the landfill than are migrating from it. Of some significance is the fact that the concentrations of the detected chlorinated organic compounds found in the two core samples are low.

It must be kept in mind, however, that core samples taken from two locations only are not necessarily representative of the total site.

2. The air analyses carried out by Sciex, using the TAGA technology, indicate that the concentrations of toxic chemicals present in gases emitting from monitoring boreholes on the top of the landfill, and in neighbourhoods around the site, are comparable to concentrations of the same chemicals in other areas in Hamilton remote from the Upper Ottawa Street Landfill site.

Air analyses conducted by Mann Testing Laboratories, using the gas chromatography-mass spectrometry (GC-MS) technology, on gas venting passively and during pumping experiments on vents located along the Stone Church Road side of the site indicate the highest concentrations of volatile organic compounds, including some chlorinated hydrocarbons, in gases sampled directly from the vents.

Air tests conducted offsite in surrounding neighbourhoods indicate that the concentrations of organic compounds decrease dramatically as one moves away from the vents and are comparable to background levels of the same chemicals at other selected locations in Hamilton.

The results of these chemical analyses indicate that at the present time exposure to chemicals that endanger health is not significantly greater in the residential areas adjacent to the landfill than elsewhere in Hamilton. Nevertheless, the landfill itself is clearly a source for the emission of toxic volatile chemicals into the environment.

Therefore, the Committee recommends that a gas collection and flaring system be installed on the landfill.

The results of a feasibility study indicate that it is possible to collect and flare the landfill gas. Consequently, the Committee believes that collecting and flaring landfill gas is a practical means for decreasing the potential exposure to landfill contaminants, reducing the potential adverse impact on the environment of the total mass load of landfill gases being emitted from the site, and significantly decreasing the odour problem, which is a constant and continuing concern to residents.

3. Extensive organic analyses of leachate (i.e., the liquid that is produced by water percolating through material deposited in a landfill) have been carried out by Mann Testing Laboratories. The leachate contains many chemicals, some of which are chlorinated.

Extensive testing (primarily measurement of water chemistry parameters) of the Red Hill Creek, downstream from the landfill, has been carried out by the Ministry of the Environment. Results indicated that the

landfill is contributing pollutants to the creek but that their concentrations decrease to background levels at Albion Falls. Limited organic analyses carried out by the Ministry indicated no appreciable amounts of organic compounds in samples taken from the Red Hill Creek, either upstream or downstream of the landfill, at the present time. There are sources from which heavy metals and bacterial pollution are entering the Red Hill Creek upstream of the landfill. The Red Hill Creek both upstream and downstream of the landfill is unsuitable as a drinking water supply or as a contact recreational resource.

The Committee is undertaking seasonal monitoring of water at locations on the Red Hill Creek downstream from the landfill and of leachate in the collection system leading to the sanitary sewer.

4. Mutagenicity studies of landfill gas did not detect mutagenic activity in the gases that were sampled. Studies of air-borne particulate matter suggest that mutagenicity levels of samples collected at the landfill are comparable to those at other locations in Hamilton.

Mutagencity assays on leachate clearly indicated the presence of low levels of mutagenic chemicals, which are near the limits of detection of the assay used, in one borehole on the landfill. Samples from a second borehole and from the Red Hill Creek downstream gave some indication of the presence of low-level mutagenic compounds but failed to produce a clearcut positive response.

5. A team of hydrogeologists from the University of Waterloo, led by Dr. John Cherry, is conducting an extensive study of the movement of contaminated groundwater from the site, the first such detailed study in Canada of movement through fractured rock. The effects of the mounded water table within the landfill, in conjunction with the local topography and the fractured rock, suggest possibilities for underground movement of contaminated groundwater in many directions and at variable rates of flow. Results to date confirm the findings on general groundwater movement of earlier studies commissioned by the Regional Government; the general direction of groundwater flow corresponds to the water table slope, which is from west to east. The contaminated groundwater plume appears to be moving through horizontal fractures towards Albion Falls. There is potential for some flow through vertical fractures into deeper zones.

Preliminary investigations on the chemical nature of the contaminated plume failed to detect chlorinated organic compounds.

Since area residents are served by city water supplies, contaminated groundwater is not an immediate concern. Nevertheless, the hydrogeological aspects of the landfill may present a serious long-term environmental problem if contaminated groundwater migrates towards the escarpment.

6. In addition to major analytical studies on air, leachate, surface and groundwater, the Committee has carried out several small-scale studies on other aspects.

A feasibility study on geophysical techniques demonstrated that ground penetration radar, magnetometer instruments, and electromagnetic techniques, could not be used to detect barrels of wastes that might be buried in the landfill.

A study carried out on several animals trapped on or near the landfill did not show abnormalities, significant levels of toxic chemicals, or other unusual findings.

A study comparing the rates of absenteeism due to illness among children attending Blessed Kateri Tekakawitha Separate School, located near the landfill, and children attending schools on the west mountain and in Stoney Creek, indicate that there is little difference between average absence rates for students attending these three schools. The west mountain school appears to have the highest rate of absenteeism, followed by Blessed Kateri and the school in Stoney Creek.

7. Information on the health effects associated with exposure to chemicals that have been detected or tentatively identified as being present in the landfill has been compiled for the Committee by Dr. Robert Willes, a toxicologist with F.D.C. Consultants, and Environ, a Washington-based Environmental consulting firm. This has served to guide the analytical work, to develop toxicity profiles for selected chemicals, and to develop an analytical framework for designing the health studies.

8. Health studies, consisting of questionnaire surveys of workers and of residents, have been designed. These studies are being conducted sequentially. Landfill workers represent a potentially high-dose exposure subgroup and, therefore, may be a sensitive indicator of the potential health effects associated with exposure to chemicals in the landfill. The workers' study will be incorporated in a subsequent, larger-scale study of residents. Field work on the residents' health survey is anticipated to begin in the fall of 1983.

Conclusion

The analytical results of the Committee's investigation to date indicate that the complex mixture of chemicals present in the air in the residential neighbourhoods in the immediate vicinity of the landfill are currently not significantly different in either type or amount from the chemicals present in the atmosphere in other areas of Hamilton remote from the landfill. Therefore, it is unlikely that living in the Upper Ottawa Street landfill area poses a current health hazard to residents. This, however, does not preclude the possibility of health problems resulting from past and future exposure to chemicals emitted from the site.

INTRODUCTION

In October of 1980, the Regional Municipality of Hamilton-Wentworth closed the Upper Ottawa Street landfill, which is located on east Hamilton mountain, because a new alternative facility was developed. There was also public concern about possible exposure to toxic chemicals that might be buried there. At the same time, the Region requested the Ontario Government's Ministry of Health to carry out a health study and Dr. Arthur Bourns, a chemist, was appointed to chair a Study Committee. The members of this Committee include Dr. Dennis McCalla, a biochemist, Mr. Sandy McCallion, a steelworker, and Dr. James Osbaldeston, a physician. Ms. Anne Koven serves as Director of Research for the study.

The Committee's terms of reference are: a) to investigate the chemical nature of the materials deposited in the landfill site and their changes in that environment, and the migration of chemicals away from the area, b) to study the possible existence at or about the landfill site of a hazard to human health, and c) to consider other such matters brought out in the course of the Committee's activities which are relevant to the terms of reference.

The Committee recognized that an important element of the investigation was to obtain the support and confidence of the community. The Committee requested the Ministry to fund an independent consultant for the residents. The Upper Ottawa Street Residents' Association selected Dr. Steven Safe, an environmental toxicologist, and the Committee has worked closely with Dr. Safe.

The Committee began to plan its investigation in April of 1981. The first task was to formulate a sequential study approach. This consisted of efforts to determine from records what was buried in the landfill, to examine the landfill itself and the environment around it for chemicals, and to examine the health of workers and residents to determine what ill health effects, if any, might be attributable to exposure to landfill chemicals. The Committee recognized that the investigation was the first of its kind in Ontario and would be viewed as a prototype with application to problems at other landfills in the future.

From the early 1950s until it was closed in 1980, the landfill received all types of domestic and commercial waste as well as solid and liquid industrial wastes. What began as a rural quarry dumpsite is now a 90 foot high garbage mound covering about 40 acres. Figure 1 shows the location of the landfill and the areas around it which are referred to in this Report. Upper Ottawa Street and the Quinndale neighbourhood, which contains two elementary schools, Blessed Kateri Tekakawitha and Cecil B. Stirling, and houses within approximately 500 yards of the site, are on the west side. The landfill is bordered directly on the north side by the Red Hill Creek and houses along Limeridge Road are about 500 yards to the north of the Creek. The railway tracks form the eastern boundary of the site, beside which is located a conservation park area. Albion Falls is within one mile of the site to the east. Stone Church Road is along the southern end of the landfill and a light industrial development is located across the street.

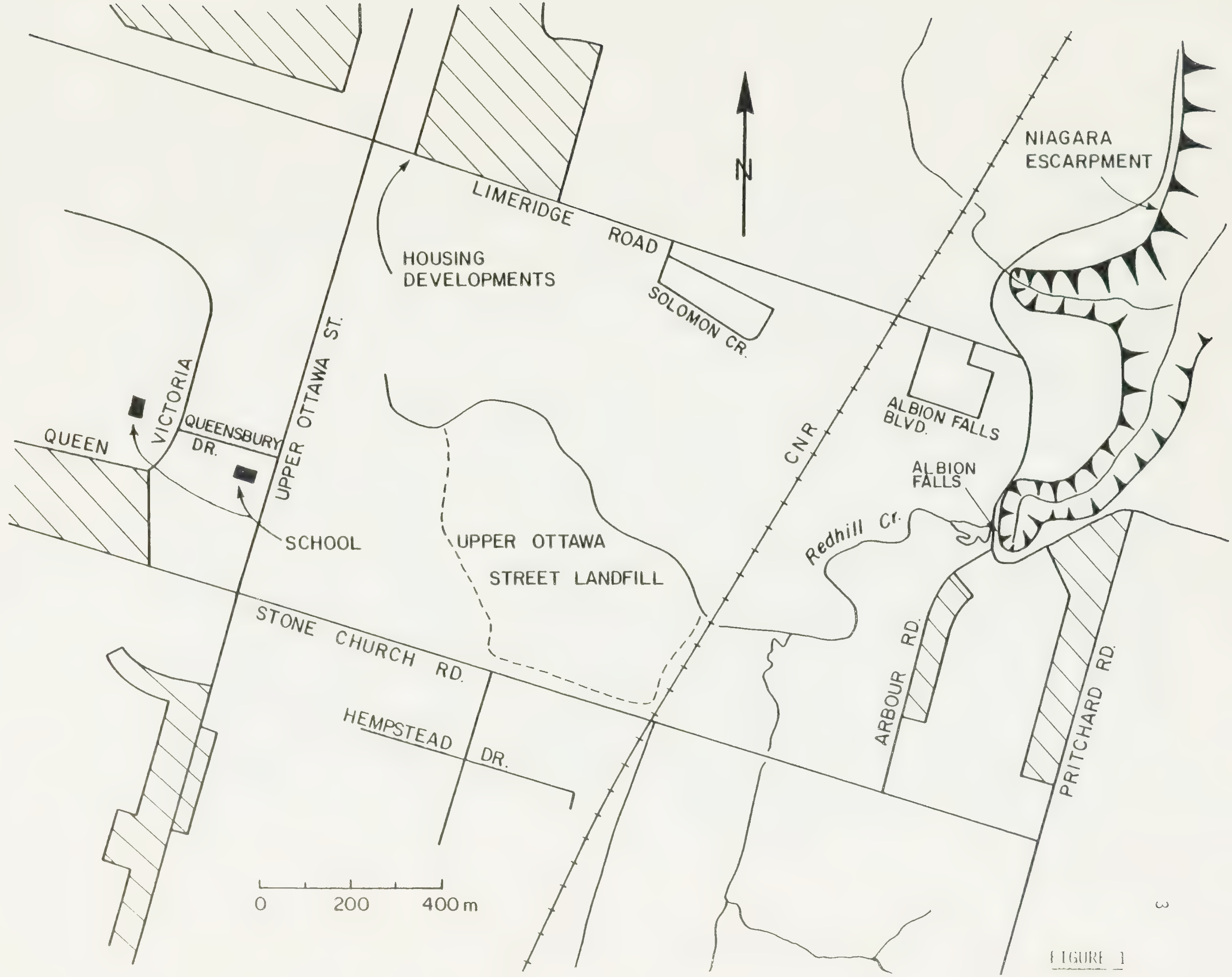
N
NIAGARA ESCARPMENT
LIMERIDGE ROAD
HOUSING DEVELOPMENTS
SOLOMON CR.
ALBION FALLS BLVD.
ALBION FALLS
CNR
Redhill Cr.
UPPER OTTAWA ST.
VICTORIA
QUEENSBURY DR.
QUEEN
SCHOOL
UPPER OTTAWA STREET LANDFILL
STONE CHURCH RD.
HEMPSTEAD DR.
ARBOUR RD.
PRITCHARD RD.
0
200
400 m

FIGURE 1

It became apparent to the Committee in the early stages of its investigation that existing records on wastes disposed in the landfill were not very useful because they are incomplete and nondescriptive. Therefore, a large amount of analytical work was required to identify potentially toxic substances contained in the landfill and, more importantly, those which are migrating from it. In the context of analytical chemistry, it is important to note the development of new detection techniques and instruments has made it possible to detect chemicals at levels of one part per billion or even lower. It would not have been possible as recently as ten years ago to detect many of the chemicals that are being observed in trace amounts in the Upper Ottawa Street landfill.

Although the major focus of the chemical studies commissioned by the Committee has been on the air, surface water, leachate and groundwater migrating from the site, some attention has been given to the chemical content of the landfill by analyses of core samples from boreholes penetrating the landfill itself. There are two reasons for doing this. Analysis of substances migrating at the present time does not provide a complete picture of the chemicals to which residents and workers may have been exposed prior to the closure and covering of the landfill. There is also the question of whether or not there are chemicals buried in the landfill that are not being detected at present but which could be expected to migrate sometime in the future.

The Committee decided that it was neither practical nor affordable to drill the hundreds of boreholes that would be required to obtain a complete picture of the buried wastes. It was possible, however, to obtain core samples from the drilling work required to replace broken installations and these have been analyzed by Mann Testing Laboratories.

The Committee's first concern was with air tests because airborne contamination is the most likely potential route of exposure for area residents. Contamination of drinking water is not a problem because the area is served by the municipal water supply. Prior to the initiation of the Committee's study, the Ministry of the Environment had obtained some air data indicating the presence of small amounts of potentially toxic organic compounds in the vicinity of the landfill. The Committee retained Sciex, a scientific research and instrument company located in Toronto, to undertake air quality surveys at the landfill and in surrounding neighbourhoods. Sciex was selected as one of the companies to do this work because it had developed a promising new analytical mass-spectrometer, known as the TAGA 3000, which is particularly sensitive in detecting organic compounds in air.

The second company selected for air testing was Mann Testing Laboratories Ltd., in Rexdale. Mann Testing Laboratories specialize in gas chromatography-mass spectrometry (GC-MS) analysis, which has become the standard method for analysis and identification of trace organics in complex chemical mixtures.

It was deemed necessary to employ two different techniques for air testing because of the complexity of the chemical mixtures being analyzed and the need to carry out a thorough evaluation.

Parallel to these analytical studies, the Committee addressed the question of the feasibility of collecting and burning the landfill gas. Given the size of the landfill, it can be expected that large amounts of landfill gas are being formed, mostly by the decomposition of organic matter, and that this gas could carry with it potentially toxic gases resulting largely from industrial wastes that were deposited with the domestic wastes. The explosive hazards of landfill gas (methane) migration have been well documented in the literature but it is the potential for exposure to toxic compounds present in the landfill gas that concerns the Committee from a public health perspective. In addition, the extremely unpleasant odour in the vicinity of the site is a constant annoyance to the residents and serves to heighten their concern about the possible health hazards of the landfill.

After receiving proposals from four companies, the Committee retained Conestoga-Rovers & Associates Limited (CRA) to study the feasibility of collecting and flaring landfill gas. It was important to show not only that the landfill gas could be collected and burned, but that combustion conditions could be established which would destroy essentially all toxic pollutants present in the gas stream. Mann Testing Laboratories, therefore, were asked to do GC-MS analyses on the gas before and after flaring. Gas is being flared at other landfills in Ontario and elsewhere but, surprisingly, no work has

been done on the efficiency of combustion or on the possibility that other toxic chemicals could be formed during the combustion process, especially from chlorinated hydrocarbons.

The Committee decided that extensive organic analyses of leachate and surface water were also required. The Ministry of the Environment and the Regional Laboratories had done considerable analytical work on these, but that work consisted primarily of analyses for metals and the determination of broad chemical parameters such as biochemical oxygen demand (BOD) and total organic carbon (TOC) with some limited organic identification.[1] While toxic metals (e.g., iron, lead, chromium) are present in the landfill, these do not seem to be migrating from the site in leachate or surface water. This is consistent with the observation that there is low metal migration when metals have been co-disposed with domestic garbage.[2]

It is the organic compounds, however, which are likely to be the most dangerous toxic substances contained within the landfill and, as in the case of air testing for toxic chemicals, their identification in the leachate and surface water is considered to have high priority. One reason for this is that a thick cover has been placed on the closed landfill and, consequently, air tests might not detect many of the compounds to which persons may have been exposed when the landfill was operating. Also, compounds that might not be detected in the air because of their low volatility might be found in the leachate.

An additional important factor calling for extensive leachate analysis is that leachate flows from springs on the mound into Red Hill Creek, which forms the northern boundary of the landfill, thereby potentially exposing people downstream to landfill contaminants. Furthermore, leachate from the south and west sides of the landfill is now being collected and piped into the sanitary sewer system. Although dilution will be large, it is, nevertheless, important to know the extent to which pollutants of a toxic nature are entering the sewage system from the site.

The Committee employed Mann Testing Laboratories to carry out detailed organic analysis of leachate and surface water by gas chromatography-mass spectrometry (GC-MS) techniques.

A major concern in any situation involving human exposure to chemical pollutants is the possibility that these compounds may cause cancer. The Ames assay, although it is not as definitive as animal testing, provides a relatively simple means of screening compounds for mutagenic activity and, therefore, of detecting possible carcinogens. After receiving proposals from three organizations, the Committee selected Mutatech Inc. of Toronto to undertake a program of Ames assays of leachate and air particulates. At the same time, consideration was given to extending the tests to the landfill gas, as distinct from air particulates, although there is as yet no generally accepted methodology for this kind of application.

Before this program was underway, publicity was given to the results of an independent Ames test of landfill gas. As a result, the initial work by Mutatech was directed toward assessing the mutagenicity of gas.

In the opinion of the Committee, the hydrogeological aspects of the landfill present the most serious future hazard to the environment. Gartner Lee and Associates had completed a hydrogeological study for the Region in 1980. This study, although limited in scope, indicated the landfill had contaminated the groundwater and the contaminated plume was moving east towards the face of the escarpment, less than a mile from the landfill. The landfill, which is situated on fractured bedrock, presents serious problems because very little is known about the flow characteristics of contaminated groundwater in bedrock, including the attenuation* of organics and other toxic chemicals.

The Committee retained the services of Dr. John Cherry, University of Waterloo, one of Canada's foremost hydrogeologists. Dr. Cherry designed a multilevel device for groundwater monitoring in fractured rock for the study and is currently proceeding with a major investigation of groundwater at the site.

The Committee recognized that in order to have as clear a focus as possible for its health studies, detailed toxicological information was needed on the many compounds detected and tentatively identified in its analytical work. Although toxicology research related to landfills is more advanced in the United States than in Canada, the Committee decided to call on Canadian expertise for this project. Dr. Robert Willes, a toxicologist with F.D.C. Consultants, was retained to provide toxicological input for the analytical work and

---

*Attenuation refers to the reduction in concentration of contaminants as they move through the bedrock in groundwater.

to develop toxicity profiles for selected compounds. Dr. Willes' work was supplemented with toxicity research by Environ, a Washington-based environmental consulting firm that has a computerized data base on toxic chemicals.

The Committee was aware from the outset that the analytical work would not identify all of the compounds present in the landfill and that lack of detailed toxicological knowledge of many of the identified compounds would impose a further limitation. For this reason, the health studies should be designed so as to detect a wide range of possible health effects related both to the identified chemicals and to chemical exposure generally.

Work on designing the health studies was planned to proceed concurrently with the analytical work. An Advisory Health Group, chaired by Dr. William Goldberg, was established. This group requested an assessment of the feasibility of an epidemiological investigation of the health impact of the Upper Ottawa Street landfill on workers and local residents. Designing health studies of the type needed is hindered because there is a) no established methodology for such studies, b) the duration of exposure for most residents is less than six years, which is too short a time for potential chronic effects such as cancer to be detectable, and c) the likelihood of being able to establish a cause and effect relationship between illness and the landfill is small because of the problems of isolating landfill exposure from other types of chemical exposure.

The Committee is in the process of carrying out a health survey of former landfill workers and other persons working near the landfill to be followed by a residents' health study. The workers' study is being carried out under the direction of Dr. David Muir, Director of the Occupational Health Program at McMaster University. Dr. Clyde Hertzman, also at McMaster University, and Dr. Joseph Highland, an expert in the United States on issues of health related to landfills, are the principal consultants for this study.

2. CHEMICAL ANALYSES

2.1 Chemical Content of the Landfill

Ideally, the Committee would like to have direct knowledge of the wastes that were deposited in the landfill. This would have greatly assisted the analytical studies on air and leachate, would help distinguish between substances buried in the site and those produced by decomposition of household garbage and would give an indication of the potential long term hazards of the site.

In fact, on the basis of available information on dumping practices at the site, it is probable that the nature and amounts of wastes that are buried in the landfill will never be known with any degree of certainty. There is no accurate or complete record of the types and amounts of wastes that were placed in the landfill.

During the 1960s and early 1970s, the City of Hamilton periodically kept traffic records of vehicles entering the site. In the absence of a description of the types of wastes that were being transported, these records are not helpful in assessing the hazardous nature of the site. In 1975, the Regional government made efforts to institute a liquid waste summary recording system. The description of the wastes was very broad (e.g., oily water, sludge) and not helpful in identifying the chemical nature of the waste materials.

For many years the Regional Laboratories have analyzed samples of leachate, water from the Red Hill Creek below the landfill, and materials from liquid

waste tankers. These analyses are useful in describing some general characteristics such as conductivity, metals content and alkalinity. The Regional Laboratories, however, are not equipped to do sophisticated organic analysis and, therefore, are not able to provide specific identification of potentially toxic organic compounds.

In 1977, the Ontario Ministry of the Environment implemented a waybill system, which was designed to identify the waste generator, the waste hauler, the amount and type of waste being transported and the disposal location. This system, however, was open to oversight and abuse. Lost records, uninformative descriptions of waste materials and identification of the waste hauler, but not the waste generator, were among the problems encountered.

While the Upper Ottawa Street landfill was the site for disposal of many types of solid and liquid wastes, it is the industrial liquid wastes that are the greatest cause for concern. Prior to 1970, it would appear that a comparatively small volume of liquid wastes was being deposited at the site. Available records suggest that about 225,000 gallons of liquid wastes were disposed of in 1970*. Of this amount, the Region estimated that about 90 per cent originated locally from steel-related industries.

---

* Estimates of wastes deposited in the landfill are based on a review of existing records, which are acknowledged to be incomplete, and, therefore, may be underestimated.

The amount of liquid waste disposed of at the landfill increased rapidly during the 1970s, reaching an estimated 8 to 10 million gallons in 1978. One reason for this was that other landfills in Hamilton and outside of the Region had reached capacity and began to close; consequently, industries and waste haulers were obliged to find alternative waste disposal sites. Since the closing of the Upper Ottawa Street landfill, there has been no liquid waste facility operating in the Hamilton-Wentworth Region.

The single most important reason for the increase in volume of wastes deposited at the landfill was the opening of a privately owned 'solidification/chemical fixation' operation at the site in late 1976. This plant employed a proprietary process to transform inorganic liquid wastes (primarily sludges containing heavy metals which were stored in open lagoons) into solid form. Fixation took place in a mixing tank and the resulting product (i.e., 'inert' material) was landfilled.

The solidification business also attracted wastes from outside the Region. It has been roughly estimated that up to 25 per cent of the wastes treated by solidification were transported from other locations in Ontario. Additionally, a United States' Congressional Subcommittee on Oversight and Investigation learned from a survey that a minimum of 5800 tons of liquid wastes were sent to a processing plant in Hamilton by at least two American chemical companies between 1975 and 1978. According to Ministry of the Environment's records, these wastes were organic solvents, which were processed for fuel. Some of the water from this process was landfilled at the Upper Ottawa Street site.

The basic lack of information about waste materials deposited in past years at the Upper Ottawa Street site and other landfill sites presents a major stumbling block to designing specific studies to investigate the possible health effects of exposure to landfill contaminants. Additionally, companies that used the landfill are reluctant to disclose information about formerly acceptable practices that are now being criticised. These political and legal aspects further complicate the task of carrying out a thorough study of the problem.

In principle it should be possible to determine analytically the chemicals present in the landfill. However, this would require drilling hundreds of boreholes in the 90 foot high 40 acre site in order to sample wastes buried there on a comprehensive basis. Even if this were done, one would not know with certainty if all toxic substances were being detected or if a toxic substance found in one or two locations is more widely dispersed in the landfill.

Nevertheless, the Committee did take advantage of the fact that two replacement boreholes were drilled on the mound (near the former solidification lagoons and on the east end of the landfill) during the study by having chemical analyses performed on the core samples so obtained. Mann Testing Laboratories analyzed six of these samples taken from depths ranging from 25 to 85 feet. Organic analysis of core extracts as well as 'headspace analysis'* for volatile components in the soils were carried out on each sample.[3]

---

*This involves heating a core sample in a closed container to vapourize the volatile components in the sample for subsequent analysis.

Mann Testing Laboratories' analysis of core samples, as well as liquid, sediment and gas samples, was by capillary column gas chromatography-mass spectrometry (GC-MS), which can detect organic compounds at a limit of approximately one part per billion. Gas chromatography separates the mixture of chemicals present in a sample, and the electron-impact mass spectrometer fragments some of the molecules and measures the M/Z ratios* of the resulting ions as well as the M/Z ratio of the parent compound.

The data thus obtained are stored in the memory of the computer and matched with the spectra from the United States Environmental Protection Agency/National Institute of Health computer "library", which contains mass spectra of 33,000 compounds. The computer then lists the three compounds which give the best match to each unknown compound and also gives a numerical indication of how well the two spectra match.

The core samples contained large amounts of petroleum-derived hydrocarbons and polynuclear aromatic hydrocarbons (PAH's), the latter ranging in concentrations from less than one part per million to 30 parts per million. Polychlorinated biphenyls (PCB's) were also found at five parts per million and less. No significant amount of chlorinated organics other than PCB's was found in any sample.

---

* These are the ratios of the mass of the molecular ions to their electrical charge.

The headspace gas analysis detected alkyl benzenes, naphthalene and volatile chlorinated solvents, specifically dichloroethane, dichloroethylene, trichloroethylene and tetrachloroethylene. This analysis was completed before the air tests performed by Mann Testing Laboratories and provided evidence that chlorinated solvents, which were expected to be in the landfill, are actually present. Toluene was found in concentration of over 100 parts per million and chlorinated ethylenes in the range of 10 parts per million. Large variations were found in types and amounts of compounds between the two boreholes and at different depths within each borehole.

The core analysis presaged the results obtained in the gas collection and flaring experiments; a greater variety of chemicals in much higher concentrations are found within the landfill than are currently migrating from it in air, leachate, surface water and perhaps groundwater.

2.2 Air Analyses

2.2.1 Trace Atmospheric Gas Analysis (TAGA)

The Committee devised a two stage program for the Sciex air tests. The first stage involved extensive air quality surveys which were carried out using the Sciex TAGA 3000 mass spectrometer.[4] This instrument converts compounds into charged species (molecular ions) by a chemical ionization process and then separates these species according to their mass and ionic charge. The values obtained are the ratios of the mass of the molecular ions to their electrical charge (designated M/Z). The limitation of the TAGA 3000 technology is that several different compounds can produce molecular ions having the same M/Z value so that it is not possible to establish which of the several possibilities is actually present in the sample being analyzed. For example, in the air quality survey a molecular ion having M/Z of 75 was detected near the landfill. Substances that might have given this value include butyl alchol, diethyl ether and dimethyl nitrosamine. Of these, the first is an industrial solvent, the second was formerly widely used (at high concentrations) as an anesthetic and the third is a powerful carcinogen. Obviously, the TAGA 3000 data may have indicated the presence of a potentially serious problem but additional information on the true identity of the compound was needed to assess whether or not a hazard exists. On further analysis this compound turned out to be butyl alcohol.

In this first stage of investigation Sciex established M/Z values for 273 compounds present in the air in the vicinity of the landfill. From the M/Z values observed in the air survey, the Committee requested Sciex to develop a list of candidate compounds for further research based on their possible toxicity and use as industrial agents. This provided the Committee with an indication of the most hazardous possible situation that could exist given the preliminary analytical results obtained.

More detailed toxicological data for approximately 100 of the compounds so presented were then sought, with the help of a consulting toxicologist. After reviewing these data, the Committee finally selected a list of the 'worst case' chemicals, numbering 31 in total. These included carcinogens, reproductive toxins, and compounds that had the potential of being converted into carcinogens (nitrosation substrates). This list provided the focus for the second stage of work.

In the second stage of Sciex's work, verification analysis was carried out using Sciex's newly developed TAGA 6000 or MS/MS instrument.[5] This double mass spectrometer first separates molecular ions from one another, as with the TAGA 3000, and then, in a second stage, fragments these "parent" ions into ions having lower M/Z values. The complex fragmentation pattern so produced is characteristic of the specific chemical substance involved. By comparing the fragmentation pattern of a standard (i.e., pure commercial samples of the candidate compounds) for each of the 31 'worst case' possibilities with that of the compounds actually found in the air, it was possible to establish for each whether or not the 'worst case' tentative identification was correct.

For only five of the 31 compounds that have undergone verification and quantification work were the tentative 'worst case' identifications confirmed. The verified compounds are acrylic acid, phenol, cresols, xylenols*, and methyl pyridine. The identification of carbaryl was inconclusive but in subsequent quantification work the assumption is made that it is present.

The identities of the remaining 24 selected compounds were shown not to correspond to the 'worst case' possibilities. The alternative possibilities for the identities of these substances suggest that they are compounds of low toxicity.

The next stage of the investigation was to carry out a quantitative survey of the six confirmed toxic compounds (including carbaryl) in air sampled from eleven locations in order to examine the general occurrence of these chemicals in the Hamilton area. These locations include sites upwind and downwind of the Upper Ottawa Street landfill; a residential control neighbourhood on the west mountain; locations in the industrial and downtown areas of Hamilton; and sites upwind and downwind of a domestic landfill in Ancaster.

The results, which are presented in Table 1, show that the confirmed compounds were present at all sites sampled and occurred upwind as well as downwind of the Upper Ottawa Street landfill. Further, with the exception of acrylic acid, they were found at much higher levels elsewhere than at this landfill.

---

* There are several isomeric cresols and xylenols and the TAGA 6000 did not distinguish between them.

TABLE 1

TAGA SURVEY

SUMMARY OF QUANTITATIVE RESULTS FOR THE CONFIRMED CHEMICALS AND CARBARYL

(in parts per billion)

Sampling Site	Methylpyridine	Carbaryl	Acrylic Acid	Phenols	Cresols	Xylenols
Threshold Limit Value (TLV)*	5,000	5,000	100,000	5,000	5,000	No Value Set
1981 Survey						
Tekakawitha School	0.010	0.002	1.22	0.15	0.001	0.50
10 meters west of the Landfill Gate	0.008	0.001	1.37	0.04	0.001	0.35
Lime Ridge Road near railroad tracks	0.016	0.018	3.49	0.15	0.005	1.11
Stone Church and Upper Ottawa	0.024	0.015	4.72	0.23	0.007	1.25
Arbour Street	0.011	0.014	3.16	0.11	0.004	0.95
1982 Survey						
i) Upper Ottawa Landfill-						
Upwind (Near Limeridge and Upper Kenilworth)	0.22	ND	0.74	0.15	0.004	0.40
Downwind (Stone Church)	0.12	0.07	0.87	0.10	0.003	0.34
ii) Ancaster Landfill-						
Upwind (near Hwy. 2 and Shavers Road)	0.07	ND	0.38	0.08	ND	0.26
Downwind (at Gate)	0.09	0.05	0.43	0.05	ND	0.25
iii) Other Areas in Hamilton Remote from the Landfill						
Stone Church West (by the Reservoir at Garth St. - res.)	0.10	ND	0.80	0.07	0.003	0.65
King Ridge Plaza on Limeridge Road West (res.)	0.12	ND	0.42	0.06	0.002	0.46
Chester Avenue (res.)	0.01	0.03	0.68	0.22	0.003	0.94
Burlington and Stapleton (indust.)	3.17	0.20	3.60	1.29	0.017	1.94
Mahony Park (indust.)	0.00	ND	ND	ND	ND	ND
Ottawa/Parkdale/Barton/Burlington (indust)	0.01	ND	ND	0.33	ND	ND
Gage Ave. at King St. (res.)	0.63	0.10	2.22	1.28	0.29	44.54

*Threshold Limit Values represent what is thought to be the maximum 'safe' permitted exposures for workers to certain chemicals during an 8 hour working day, or 40 hour working week.[6]
(See page 67 for a discussion of TLV's in relation to environmental exposures.)

(res.) = residential area (indust.) = industrial area ND = not detected

In addition to the major air surveys and the verification programmes described above, Sciex subcontracted analyses of chlorinated compounds to Wellington Environmental Consultants during the summer of 1981, because the TAGA 3000 was not equipped to detect this class of compounds. Wellington's results indicated that no significant amounts of chlorinated organic substances were present in the landfill gases. By the summer of 1982, the TAGA 3000 was adapted to monitor chlorinated hydrocarbons. A survey conducted for these compounds indicated that no chlorinated hydrocarbons could be detected at concentrations of greater than one part per billion, which is the detection limit of the system.

During the summer of 1981, Sciex also carried out, for the Ministry of the Environment, qualitative air surveys of gases emitting from three vents on top of the Upper Ottawa Street Landfill. These results were similar to those found in the Committee's tests: numerous organic compounds were present in concentrations in the low parts per billion range.

The large amount of effort that went into Sciex's work to produce, in the end result, the verified identification and quantification of only a few chemicals, is a result of the low concentrations of most pollutants, the complex chemical nature of the landfill, and the limitations inherent in applying new technology to a new research field.

2.2.2 Conventional Gas Chromatography Mass-Spectrometry (GC-MS)

Mann Testing Laboratories completed core and leachate analyses prior to air testing at the landfill and these results are presented in sections 2.1 and 2.3 of this Report.

To date, Mann Testing Laboratories have conducted two different air testing programs for the Committee. The first was an organic analysis of pre-flared landfill gas samples collected in air bags and Tenax tubes* during the gas collection and flaring experiments done by Conestoga-Rovers and Associates Limited (CRA).[7] (See following section 2.2.3.) The second test was an air survey using Tenax sorbent tubes.[8]

The Tenax approach is a different sampling technique from that used by Sciex. Air was drawn through the Tenax tubes by pumps, and chemicals present in the air were adsorbed on the Tenax and then desorbed and analyzed by capillary column gas chromatography-mass spectrometry. Further refinements, such as increasing the volume of air pumped through the Tenax tubes in order to increase the ability to detect compounds present in very low concentrations, are planned.

---

* Tenax is a material which adsorbs organic compounds from air and can, therefore, be used to collect such compounds for analysis. The Tenax tube is then attached to the sampling inlet of a gas chromatograph and warmed so that the organics are released and analyzed.

Pre-Flared Landfill Gas Analysis

The primary objective of analysis for Conestoga-Rovers & Associates Limited's (CRA) work pertained to the combustion efficiency of the flare technique, but the results were also important in providing new information on the identity of chemicals in landfill gas.

Analysis of air bag and Tenax tube samples of pre-flared gas pumped from the landfill and of water condensate from the flare device during CRA's first experiment indicated the presence of several volatile organic compounds - acetone, methyl ethyl ketone, toluene, xylenes - in high concentrations. The pumped well gas also contained significant amounts of aliphatic hydrocarbons, chlorinated solvents, low molecular weight alcohols, tetrahydrofuran, 1,4- dioxane*, ketones, and alkyl benzenes. The results of quantitative work subsequently carried out by Mann Testing Laboratories on the pre-flared gases pumped from the landfill are shown in Tables 3 and 4 in the following section 2.2.3 of this Report dealing with the gas flaring experiments.

The results of the analytical work on the pre-flared gases are especially significant because a number of these volatile organic compounds, including the chlorinated hydrocarbons, were not detected or were found in extremely low concentrations by Sciex.

---

* This compound is not to be confused with the toxic polychlorinated dibenzo-*p*-dioxins, which are a class of compounds referred to as dioxins.

The reason for the relatively high concentrations observed in this work was first thought to be related to the fact that CRA drilled a gas well into the garbage mound and then pumped the landfill gas to the surface at a constant rate. There was some speculation that the pumping of gases from this depth brought to the surface heavy organics that were not escaping passively either through the cover or the gas vents on the landfill in high amounts. It was observed, however, in subsequent pumping experiments and analytical work described in section 2.2.3 of this Report, that active pumping does not significantly increase the concentrations of most volatile organic compounds. (See also page 34)

Air Survey

Two stages were involved in the Mann Testing Laboratories' air survey testing program in the vicinity of the landfill. In the first stage, gas samples collected from a vent on the landfill using Tenax tubes were analyzed by GC-MS. The results indicated the presence of benzene, toluene, xylenes, substituted benzenes, phenol, benzaldehyde, naphthalene and tetrahydrofuran. This work demonstrated the need for a comprehensive quantitative air survey using Tenax tube sampling.

In the second stage, a large scale quantitative survey was carried out in which air samples were collected in Tenax tubes from gas vents on the landfill, upwind and downwind sites, and in downtown Hamilton.

The results of this survey, which are shown in Table 2, indicate that the concentrations of organic compounds decrease dramatically as one moves away from a vent on the landfill.

TABLE 2

TENAX TUBE AIR TESTING SURVEY
CONCENTRATION OF ORGANIC COMPOUNDS IN AIR
(parts per billion)

	1. Gooseneck Vents	2. Quanset Hut	3. Hempstead Drive (downwind)	4. Upwind Control	5. Firehall	6. Blessed Kateri Tekakawitha School	7. Cecil B. Stirling School	8. Downtown Hamilton
Hexane	7	ND	1	ND	ND	9	ND	21
Acetone	10	ND	ND	20	ND	ND	ND	ND
Dichloromethane	102	ND	ND	ND	ND	ND	ND	ND
Benzene	17	8	9	2	4	5	5	21
Trichloroethylene	1	T	T	ND	ND	ND	ND	ND
Chloroform	35	ND	ND	ND	ND	ND	ND	ND
Toluene	62	21	42	4	2	11	4	29
Ethylbenzene	5	1	ND	ND	ND	ND	ND	5
Xylenes (total)	29	5	3	2	1	3	4	28
Styrene	10	4	5	ND	ND	ND	2	20
Sulfur Dioxide	(81)	(100)	(127)	(23)	(13)	ND	(82)	(83)
Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroethylene	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND
Dimethysulfoxide	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyldisulfide	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	ND	ND	ND	ND	ND	ND	ND	ND

( )= estimates
T = Trace
ND = not detected

Sampling Locations

1. on south side of landfill
2. on west side of landfill
3. offsite south of Stone Church Road
4. offsite northeast near Limeridge Road by Albion Falls
5. directly beside landfill to the southwest

6.&7. west of landfill

8. corner of King St. and James St.

Indeed, the highest offsite concentrations of aliphatic and aromatic hydrocarbons were found in downtown Hamilton and not in the vicinity of the Ottawa Street Landfill.

In addition to the eight sampling sites listed in Table 2, the air survey also included samples of passive gas emissons from CRA's test well on the Upper Ottawa Street Landfill and from a well on the Ancaster landfill. It was not possible to obtain complete quantitative results from either of these wells because the Tenax tubes rapidly became saturated by the high concentrations of organic compounds in the gases. The results, however, indicate that gas sampled from an existing well on the Ancaster landfill contains higher concentrations of tetrachloroethylene, dimethyldisulfide, dimethylsulfoxide, naphthalene, dichloroethylene and dichloroethane than were found in gas sampled from CRA's test well on the Upper Ottawa Street landfill. Toluene was the only compound that appeared to be in higher concentration at the Upper Ottawa Street landfill than at the Ancaster landfill. The presence of these compounds, in high concentrations, in gas from the Ancaster landfill is surprising since, as far as is known, this site was used only for domestic garbage.

In September 1982, Mann Testing Laboratories analyzed a routine compressed air sample collected from the Hamilton Fire Department Training Centre located beside the landfill. No trace of chlorinated compounds was detected in this sample.

2.2.3 Gas Collection and Flaring

The Committee decided to investigate the possibility of collecting and disposing of landfill gases even though the toxic potential of landfill gases is not fully understood.

The Committee identified Conestoga-Rovers and Associates Limited (CRA) as having the most experience in the Province in the disposal of landfill gas by flaring. The objective of CRA's work for the Committee was to determine the technical feasibility of recovering and flaring gas generated at the landfill.

A test gas well on the Stone Church Road side of the site was installed to a depth of 32 feet in the landfill and five gas probe nests, ranging in depth from 10 to 25 feet, were spaced at distances of 30 feet to 150 feet from the well to ascertain the area over which the well would collect gas. The results of a 32-hour continuous pumping test indicated that large volumes of landfill gas in concentrations of 50 per cent to 58 per cent combustible gas (methane) by volume could be drawn as far as 150 feet from the test well. The gas flared very easily and continually during the test.[9]

While the initial experiment was successful in that it showed the site produced enough methane to maintain a constantly burning flare, it failed to answer the critical question as to whether combustion conditions could be readily achieved that would yield combustion gases that are relatively free of toxic substances, either from the site or produced in the burning process. This was because the flame was overly fuel-rich and hence inefficient (combustion temperatures ranged from 400°C to 800°C). Consequently, the

flame burned outside of the flare enclosure, which made sampling for combustion gases inconclusive due to dilution with outside air.

Corrective measures were taken and the flaring test was repeated.[10] It was found that the optimum dilution was 10 parts air to one part landfill gas. A maximum flame temperature of 950°C was observed under these conditions. Prior to flaring, oxygen was measured in the flare chamber in excess of 17.5 per cent. Approximately 11 per cent oxygen remained after combustion, indicating an efficient flame.

During this second flare experiment, it was decided that several different sampling methods and analytical techniques were required in order to permit thorough analysis of chemicals present in pre- and post-flare landfill gases.

Three gas chromatographic detection techniques were used to analyze samples collected by air bags and cylinders. A thermal conductivity detector (TCD) was used for analyzing gases that were found in the percent range (i.e., oxygen, methane, nitrogen and carbon dioxide). A flame ionization detector (FID) was used to measure hydrocarbons such as ethane and propane in parts per million range. An electron capture detector (ECD), which selectively detects halogenated compounds present in trace amounts, was used to analyze the chlorinated chemicals such as 1,1,1-trichloroethane.

Table 3 presents the results of the analysis of air bag samples of undiluted landfill gas before flaring, landfill gas diluted with 10 parts air to one part gas, and gas after flaring. Of special significance was the observation that 1,1,1-trichloroethane,

TABLE 3

CONCENTRATIONS OF COMPOUNDS MEASURED
IN LANDFILL GAS AND FLARE GASES
Air Bag and Cylinder Samples

	Pre-Flare (Undiluted Landfill Gas)	Landfill Gas Diluted with Air (10:1 Flame off)	Post-Flare (Flame On)
*A. Nitrogen	10.3%	73.6%	75.6%
Oxygen	2.9%	19.8%	12.6%
Methane	51.4%	4.1%	0.2%
Carbon Dioxide	34.0%	2.5%	7.0%
Total Non Methane Hydrocarbon	0.4%	0.03%	0.02%
*B. Ethane	21.6ppm	4 ppm	9.7ppm
Acetylene	T	0.6 ppm	1.4ppm
Propane	ND	ND	ND
*C. 1,1,1-trichloroethane	17.1 ppm	2.2 ppm	0.05ppm
Dichloroethylene	T	T	ND
Tetrachloroethylene	0.2 ppm	T	ND

* A. Thermal Conductivity Detector (TCD)
* B. Flame Ionization Detector (FID)
* C. Electron Capture Detector (ECD)

T = trace
ND = not detected
ppm = parts per million

which was present at a concentration of 17.1 parts per million in the pumped landfill gas and 2.2 parts per million in the flare chamber before combustion, was reduced to a concentration of 0.05 parts per million in the combustion gas sampled above the flare. This establishes that approximately 98 per cent of this chlorinated organic was destroyed. Two other chlorinated compounds, tetrachlorethylene and dichloroethylene, which had been detected in trace amounts before burning, were not detectable after combustion of the landfill gas.

Methane was present in 4.1 per cent concentration in the flare chimney (after mixing with air) before flaring, but could be detected in only trace amounts after combustion.

Tenax sorbent tubes were used to sample volatile compounds, particularly the volatile organics, in the landfill and flare gases. These samples were analyzed by gas chromatography-mass spectrometry (GC-MS), which, as mentioned previously, is considered to be the most effective technique for screening organic compounds.

Table 4 presents the results of the analysis of undiluted landfill gas and post-flare gas sampled by Tenax sorbent tubes. Benzene, naphthalene, and benzofuran appear to have lower combustion efficiencies than do other organic and chlorinated organic compounds present in this landfill gas flaring experiment.

TABLE 4

APPROXIMATE CONCENTRATIONS OF ORGANIC COMPOUNED MEASURED IN LANDFILL GAS AND FLARE GASES
Tenax Sorbent Tube Samples
(parts per million)

	Pre-Flare Landfill Gas (Undiluted - Flame Off)	Post-Flare Gas (Flame On)
Furan	30	1
Sulphur Dioxide	2	5
Benzene	47	9
Toluene	102	4
C_2-Benzenes	88	0.4
C_3-Benzenes	43	0.1
C_4-Benzenes	6	ND
Dihydroindene	10	0.2
Indene	1.6	0.1
Dichlorobenzene	1.9	ND
Benzofuran	0.4	0.2
Benzaldehyde	ND	0.4
C_1-Benzaldehydes	ND	0.2
Naphthalene	1.0	0.4

Analyzed by gas chromatograph-mass spectrometer (GC-MS). Amounts are relative to the concentration of toluene.
ND = not detected

It was also observed during the flare tests that the foul odour of the landfill gas was eliminated. Sulphur containing compounds were identified in the gas and these can cause strong odours even at low concentrations. It is known that these compounds are easily destroyed during combustion.

A second objective of the flare test was to determine whether toxic combustion byproducts are produced during the burning of landfill gas. Nitromethane was the only compound that had not been detected previously in the landfill gas and it was found to be produced in concentration of roughly five parts per million during combustion. Nitromethane is not toxic except in relatively high concentrations. Therefore, its occurrence as a combustion byproduct is not considered to constitute a hazard. Relatively small amounts of benzaldehyde and C_1- benzaldehydes may be formed during combustion as well. Incomplete oxidation may also result in the production of some acids, which would not be detected by the Tenax tube-thermal desorption methods used in the experiment. Styrene was present in the post-flare gas and was not detected in the pre-flare samples. This compound is not a combustion product and there is the possibility that sampling problems and laboratory contamination could account for this result.

These results show that naphthalene, a polynuclear aromatic hydrocarbon (PAH), was detected in one part per million in the flare chamber before flaring and in 0.4 parts per million after flaring. Although naphthalene may be produced as well as destroyed in the flaring process, it is clear that its overall concentration is reduced. This may also be taken as an indication that

even if other PAH's are being produced during combustion, their overall concentrations may be reduced by the flaring process. Further work on this matter is required.

Analysis of the landfill gas combustion products indicated that no chlorinated aromatic byproducts (e.g., chlorinated benzenes, phenols and biphenyls) were being formed during this process. These compounds would have been detected had they been present in concentrations of greater than one part per billion. They are precursors of the highly toxic polychlorinated dibenzo-p-dioxins (i.e., dioxins) and dibenzofurans. The results, therefore, suggest that their formation during the flaring of landfill gas is negligible.

A third issue of concern to the Committee, related to the gas collection and flaring experiments, was the possibility that active pumping of landfill gases might actually bring to the surface heavy chlorinated organic compounds, which, if left undisturbed, would not emit passively in significant concentrations through the landfill cover.

Pumping experiments and analytical work were carried out to determine if active pumping actually serves to increase the concentration of volatile organics in the landfill gas.[11] This work involved sampling gas that was emitting passively from vents on the landfill and from the CRA test gas well, both without pumping, and during a 24-hour continuous pumping experiment. The samples were collected in gas bags and analyzed by gas chromatography (GC) with flame ionization detection (FID), and electron capture

detection (ECD). Five key compounds known to be present in the landfill gas were quantified: benzene, toluene, total xylenes, 1,1,1- trichloroethane and tetrachloroethylene. These samples were also screened for dichlorobenzene but it was not detected. The landfill gas is comprised of approximately 0.5 per cent total non-methane hydrocarbons and the total amount of volatile chlorinated organics does not exceed 20 parts per million.

The results of this experiment are presented in Table 5. Continuous pumping does not appear to change significantly the concentration of toluene or xylenes.

The most important comparison that can be made from the data presented in Table 5 is the difference observed in concentrations of the chlorinated compound 1,1,1-trichloroethane. It appears that 1,1,1-trichloroethane is emitting naturally from the landfill in concentrations of approximately one part per million as measured in passive emissions of this compound in the shallow gas probes and goose neck vents. Passive emission of 1,1,1-trichloroethane in CRA's 32-foot deep test well is about six times greater than the concentrations observed in the shallow probes and vents, which suggests the presence of higher concentrations of heavier organics at depth. Of particular significance, however, are the much higher concentrations of this compound in the pumped gases. After three hours of pumping, its concentration was found to be some 11- to 14-fold greater than that present in the gas emitting passively from the shallow gas probes and goose neck vents. This substantial increase in concentration due to the pumping, however, must be considered within the context that flaring was shown to destroy about 98 per cent of 1,1,1-trichloroethane. Assuming that the behaviour of 1,1,1-trichloroethane is typical of other

TABLE 5

A COMPARISON OF LANDFILL GAS OBTAINED BY
PASSIVE EMISSIONS AND ACTIVE PUMPING
QUANTIFICATION OF SELECTED VOLATILE ORGANICS IN LANDFILL GAS
(parts per million)

	Benzene	Toluene	Xylene	1,1,1 TCE	Tetra
Shallow Gas Probe 1 No pumping	5	185	63	1.3	0.18
Shallow Gas Probe 2 No pumping	4	183	56	0.3	0.17
Goose Neck Vent 1 No pumping	6	126	64	0.6	0.19
Goose Neck Vent 2 No pumping	5	126	80	1.7	0.21
CRA Well No Pumping	N/A	172	45	5.2	0.32
CRA Well No Pumping	N/A	203	63	6.9	0.35
CRA Well Pumping 1 hour	N/A	170	61	7.1	0.16
CRA Well Pumping 3 hours	N/A	212	75	14.6	0.55
CRA Well Pumping 3 hours	N/A	327	150	11.8	0.58
CRA Well Pumping 5 hours	N/A	221	91	12.4	0.53
CRA Well Pumping 5 hours	N/A	187	75	11.5	0.40
CRA Well Pumping 24 hours	N/A	228	73	11.5	0.39
CRA Well Pumping 24 hours	N/A	216	68	11.7	0.35

N/A = not available due to interferences in chromatogram. Levels above 15 ppm would have been detected and reported.
Tetra = tetrachloroethylene
1,1,1 TCE = 1,1,1-trichloroethane
Probe 1 = gas probe nearest CRA well (Stone Church Road side)
Probe 2 = gas probe second nearest CRA well
Goose 1 = goose neck vent directly south of CRA well
Goose 2 = goose neck vent third from railway tracks
CRA Well = Conestoga-Rovers & Associates' test well on Stone Church Road side of the landfill.

chlorinated hydrocarbons, the concentrations of these compounds will be substantially lowered through burning.

It is also possible that after continuous pumping the concentrations of the chlorinated organics would decrease to the levels found in the passively venting gas. This would be expected if the gas built-up within the landfill has a higher concentration of the more dense organics. Under these circumstances, the composition of the pumped gas over time should be determined by production rates rather than by storage concentrations. It will be possible to test this hypothesis through longer pumping tests, which are recommended in this Report.

The gas collection studies carried out by Conestoga- Rovers and Associates Limited (CRA) have shown that optimum conditions exist for gas production and combustion: methane concentrations are in the high range from 50 to 58 per cent by volume; temperatures within the landfill are in the upper end of the optimum range for methane production of 30°C to 50° C; combustion efficiency for most organics is greater than 90 per cent and for the chlorinated organics in excess of 95 per cent; and toxic compounds do not appear to be formed in significant quantities during combustion.

Furthermore, a very large volume of gas is being produced. CRA has estimated a gas recovery rate from pumping in the range of 0.3 to 0.9 cubic feet per pound of refuse per year. This is high compared to typical recovery rates at other landfills of about 0.05 to 0.15 cubic feet per pound per year.

Based on estimates by Regional Government staff of a total amount of refuse in the site of 1.5 million tons, CRA has calculated that the total gas production rate may be in the order of 1.8×10^9 cubic feet (i.e., 1.8 billion cubic feet) per year.

Important factors to be considered in assessing the production of landfill gas are the quantities and types of chemical wastes deposited in the site. The Upper Ottawa Street Landfill Site is known to contain large amounts of industrial liquid wastes (see section 2.1 of this Report). Although hazardous amounts of these chemical wastes do not appear presently to be migrating in landfill gas, it is not possible to predict the nature of future gas emissions.

Of considerable significance in ascertaining the need to install a gas control system is the probable mass loading to the environment of the major toxic compounds that are known to comprise the emitted landfill gas. Assuming that CRA's estimate of a gas production rate of 1.8×10^9 cubic feet per year is reasonably accurate, that all gas being produced in the landfill is being emitted, that this rate is likely to be maintained for a prolonged period of time, and that the concentrations of the toxic substances over time will be approximately the average reported in Table 5 for passive venting (shallow gas probes 1 and 2 and goose neck vents 1 and 2), the following estimates can be made of annual mass loadings:

benzene	2,000	pounds per year
toluene	72,000	" " "
xylenes	35,000	" " "
1,1,1-trichloroethane	660	" " "
tetrachloroethylene	159	" " "

It must be kept in mind, however, that these were the only compounds that were quantified in this set of measurements because they could be readily analyzed by gas chromatography. The total mass burden of hydrocarbons can be expected to be much larger than the quantities shown above for these individual compounds. Should the concentrations of these compounds turn out to be closer to that observed by Mann Testing Laboratories after 24-hours pumping (see Table 5), then the mass loadings would be significantly higher, (e.g., ten times greater for 1,1,1-trichloroethane.)

It is the Committee's view that there are compelling reasons for collecting and burning the gases that are being emitted from the Upper Ottawa Street landfill:-

1. The total amount of potentially toxic compounds discharged from the landfill into the atmosphere is large. The estimates contained in the feasibility study suggest that over one billion cubic feet of gas are being produced annually in the landfill. On this basis it can be calculated that thousands of pounds of potentially toxic volatile substances are entering the air from the landfill. Although the concentrations of these compounds to which persons in the vicinity of the site are being exposed is low, the Committee is of the opinion that it is undesirable to continue allowing these large amounts of chemicals to discharge into the air in a populated residential area.

2. Measurements of the amounts of chemicals present in the air essentially provide a 'snapshot' of the concentrations of chemicals at the time sampling takes place. While it is reassuring that the results

consistently show only low concentrations of chemicals in the vicinity of the landfill, there is always the possibility that climatic conditions, (e.g., situations of inversion or low-lying cloud cover) could result in increased concentrations of pollutants.

3. The amounts of toxic chemicals being emitted from the landfill into the air could increase or change in unpredictable ways over time. This is a consequence of the large volumes of industrial liquid wastes that were buried in the landfill and the lack of knowledge about the types of chemical reactions that are taking place inside the landfill.

4. Chemical analyses have detected low concentrations of many compounds in the landfill that cannot yet be identified. This raises the possibility that unidentified toxic compounds may be emitting from the site.

5. The toxicity of some of the compounds that have been identified by chemical analysis is not fully understood and very little is known about the toxic effects of complex mixtures of chemicals such as those found in landfill gases and other environmental pollutants.

6. The Committee has observed that the odours coming from the landfill are always noticeable and sometimes nauseating, depending on weather conditions. The odour of the gases will continue to aggravate concerns that the site may be a hazard to human health.

7. Regardless of the outcome of the Committee's chemical analytical work and health studies, it will not be possible to convince persons who live or work or own property near the landfill that the area is completely safe as long as over one billion cubic feet of gas containing significant quantities of toxic compounds are being emitted annually. The implications of this situation range from intangible aspects such as the distress of individuals who are concerned about the safety of their environment to economic considerations such as property values.

On the basis of this assessment, the Committee recommends to the Provincial and Regional Governments that an active landfill gas collection and flaring system be installed at the Upper Ottawa Street landfill and that the first phase of this work should begin as soon as possible.

This work should be implemented in three stages, the first of which would consist of a continuous pumping and flaring test to be carried out for at least one month on three test wells to be installed on the Stone Church Road side of the site.

The Committee has carried out as thorough a feasibility study as could be achieved within its terms of reference and resources. It is now necessary to verify the findings of the preliminary tests done for the Committee by CRA and to provide data for designing a permanent gas control system. The recommended first phase pumping test must provide for further evaluation of the byproducts of combusting landfill gas and of the estimated rates of landfill gas production and recovery.

The second stage would involve the construction of a permanent installation along the Stone Church Road side of the landfill. Based on CRA's preliminary design concept, which might be modified in the light of findings in stage one, it is proposed that this installation consist of a network of wells (approximately 10 feet deep and spaced 100 feet apart), connected through lateral pipes leading to a pumping system and a flare plant, which would be located in a now vacant service building on the west side of the landfill. This collection system would use vacuum pumping to produce a negative pressure within the gas wells in order to induce gas flow through the system. The landfill gas would be pumped into the flare at a constant rate. The flare chamber would be designed to allow an appropriate mixing of gas with air to ensure efficient burning. Additional engineering features would include a centrifugal separator for removing condensate from the gas, a filter for collecting particulate matter before the gas is burned and a self-ignition feature for the flare.

This proposed system is called an "active collection system" because it uses a pumping system to collect landfill gas for flaring. The alternative collection system is referred to as a "passive system". The passive system uses positive pressure naturally existing under the landfill cover to transmit the gas for flaring.

It is the Committee's opinion that a passive system is not suitable for the Upper Ottawa Street landfill because of a) the likelihood that a large portion of the gas would continue to escape from the landfill through the cover and b) the need for a controlled flow of landfill gas to sustain a high temperature flame in the flare chamber.

The estimated cost of an active gas control system on the Stone Church Road side of the landfill, as described, would be about $600,000, with an additional annual operation and maintenance cost of approximately $50,000.

The third stage in the installation of a gas control system could involve constructing a system, similar to the one described above, on the Red Hill Creek side of the landfill. Modifications to the proposed system would be required because of the extremely steep slopes on the north side of the site.

An active gas control system on the Red Hill Creek side is estimated to cost approximately $500,000. This system would also require additional annual operation and maintenance expenditures.

CRA has recommended that the potential for energy utilization from the landfill gas flaring system be reviewed for feasibility. It should be recognized, however, that any such energy utilization must not compromise the basic design criteria of the gas system to control landfill gas emissions.

2.3 Leachate Analyses

The Committee devised a two stage program for analyzing leachate, water and sediment samples. The first stage involved having Mann Testing Laboratories conduct a comprehensive qualitative analysis for organic compounds to determine the identification, but not the concentrations, of the compounds present.[12] In a second stage, following toxicological assessment of the large number of compounds tentatively identified in the qualitative work, it was planned to undertake verification and quantification studies on selected compounds.

The qualitative survey was done by gas chromatography-mass spectrometry (GC-MS) analysis. The analytical procedures that were used were adapted from those published by the United States Environmental Protection Agency and commonly referred to as "Priority Pollutant Analysis".

Leachate was sampled from four locations: a leachate spring on the north side of the landfill below the former solidification lagoons, a former surface pool of leachate that collected on the low lying east side of the site, which residents referred to as the 'black hole', an open drainage ditch on the southwest side of the site and a culvert on the east side of the landfill near the leachate collection pump. Water samples were taken from seven locations: the Red Hill Creek upstream and downstream of the landfill, three boreholes on the landfill and two boreholes offsite (to the south and east). Sediment samples were taken from upstream and downstream sites in the Red Hill Creek, from a ditch on the southeast side of the landfill and from the 'black hole'.

The qualitative survey attempted to identify as many compounds as possible. The fact that the number detected approximated one thousand shows the complexity of the task at hand.

Polynuclear aromatic hydrocarbons (PAH's) were found in abundance in a number of locations. This is not surprising, since steel industry wastes were used as a cover material. These compounds could also have as their origins waste oil products. Significant quantities of PAH's were found in the sediments but not in the water, which is to be expected because these compounds have an extremely low water solubility.

Aromatic hydrocarbons, including benzene, toluene, ethylbenzene and xylenes, as well as phenols and alkylated phenols, were also detected.

Aliphatic hydrocarbons, which probably originate from waste petroleum products, were found in large concentrations but are of relatively low toxicity.

With the exception of two samples, only very low concentrations of chlorinated organics, including polychlorinated biphenyls (PCB's) were detected. Two boreholes on the landfill itself yielded oily liquid samples containing PCB levels in the range of 20 to 50 parts per billion (Aroclor 1254).

A liquid scintillation test failed to detect any β-emission radioactivity.

Two samples of leachate taken from the leachate collection manhole on the landfill were screened for dioxin.[13] This work was done by officials at the Health Protection Branch of Health and Welfare Canada

in Ottawa. The samples were analyzed by the TAGA 6000 instrument, which was programmed to target specifically for dioxin. No dioxins or furans were found at the detection limit of one part per trillion.

Analyses of the Red Hill Creek water downstream of the landfill and of groundwater sampled from boreholes offsite indicate that organic compounds are not migrating in appreciable amounts from the landfill. The water in the Red Hill Creek does not appear to be significantly contaminated as it flows past the landfill even though surface discharge into the creek is visible*.

In summary, some of the compounds of toxicological concern detected in samples of leachate, water, and sediment include polyaromatic hydrocarbons (with anthracene being present in the highest amounts), PCB's, benzene, toluene, tetrahydrofuran, xylenes, ethylbenzene, naphthalene, phenol, cresols, and xylenols.

---

* This finding is consistent with the conclusion reached by the International Joint Commission in its 1982 Report on Great Lakes Water Quality. The landfill site, located in the Red Hill Creek watershed which drains into the southeast corner of the harbour, has been extensively investigated by the Ministry of the Environment and was not found to be a siginificant contributor to water quality impairment of Hamilton harbour.[14]

The second stage quantification work is still in progress. Standards, (i.e., pure samples of chemicals), will be used to confirm the identity of selected compounds from the qualitative survey and to determine their concentrations. The compounds to be analyzed in this second stage will be selected on the basis of toxicological assessment. This work will be focussed on the migration of landfill contaminants in the Red Hill Creek and the sanitary sewer, which receives leachate from the pipe collection system installed around the west, south, and east sides of the landfill.

3. MUTAGENICITY ASSAYS

The analytical chemistry approach to the detection of toxic hazards described above depends upon the ability to identify and quantify individual compounds and on the existence of data concerning the potential health effects of these compounds. While this approach yields important data it does have limitations. To provide additional data, the Committee employed a "biological assay" to examine the question of whether or not mutagenic substances were present. Since most carcinogens are mutagens and most non-carcinogens are non-mutagenic, this provides a preliminary indication of the presence or absence of carcinogens.

The Ames assay is a simple, rapid, widely used and relatively inexpensive test that shows whether a chemical or a mixture of chemicals causes mutation in certain carefully constructed strains of bacteria.*

---

*The bacteria employed in this assay are unable to synthesize an essential amino acid called histidine and, as a result, grow only when this substance is supplied in the culture medium. Mutations can occur in individual bacteria that restore the ability of that cell to make histidine and to grow and form a colony that is visible to the naked eye. Mutagenic chemicals increase the rate of mutation and thus increase the number of colonies on the test plates. A test is generally considered to be positive if (1) there are at least twice as many colonies (revertants) on the test plates as on the background controls and (2) the number of revertants increases with the dose of the material being assayed. Several different strains (e.g. TA98, TA100), which respond to different types of mutagens, are needed to give comprehensive coverage.

This test is not perfect, however, since there are compounds, some in common everyday use, which are not carcinogens but are positive in an Ames assay. Furthermore, the assay itself does not measure quantitatively the cancer potency of a substance nor does it provide an estimate of health risk to humans.

The Committee retained Mutatech Inc., a company whose head, Dr. John Heddle, is a leading expert in the field, to do Ames tests at the landfill. The objectives of this program were to determine whether or not gas, air particulates and leachate emanating from the landfill contain mutagens and, if they do, to estimate the levels of activity present. An important question to be addressed by this work was whether the levels of mutagens in the air in residential areas surrounding the landfill are higher than those in residential areas of Hamilton remote from the landfill.

In order to respond to public concern about the results of independent Ames tests of landfill gas from the Upper Ottawa Street site, which purported to indicate the presence of mutagens, the research program was modified to investigate vapour phase mutagens first, rather than leachate and air particulates, as originally planned.

3.1 Air

There is no established methodology for Ames testing of vapour phase samples; therefore, Mutatech was obliged to undertake exploratory work.[15] The company developed three methods of exposing the various Ames tester strains to the vapours: a closed chamber method, a bag method, which attempted to duplicate the

methodology used by the independent investigator, and a bubbling method in which the gas to be tested was bubbled through a suspension of test bacteria. The study began as an attempt to establish which of these three methods would prove most effective for the detection and quantification of mutagenic activity. Gas vents were selected for sampling both on the basis of Sciex data indicating those richest in terms of number of compounds identified and because certain vents had been used in the independent mutagenicity experiments.

The Mutatech study found that gas sampled from landfill vents by the three methods mentioned above was not mutagenic by the two criteria that are usually used to make this determination.

The discrepancy between the results obtained by Mutatech and those reported by the independent investigator could be explained by several factors. Weather conditions were different on the days that each set of tests was done. Also, there were differences in the methodologies used by Mutatech and the independent investigator. In addition, Mutatech discovered that exposure of the test plates to sunlight for one minute results in a clear doubling of spontaneous reversion frequency.

The only way to resolve the differences would be for both parties to repeat their experiments together at the landfill. The Committee will give consideration to repeating the experiments in the summer of 1983.

The second aspect of the Ames testing program dealt with air particulate matter.[16] During the last decade, research on mutagenicity of air has found that many organic contaminants are found on the surface of air particulates and that particulates in the size range

from 10 micrometers downward penetrate deep within the lungs and lodge there.

Samples of air particulate matter for the Ames test were collected from ten locations: four sites on the landfill, the Bell Canada building and fire training centre to the immediate south and west of the landfill, Blessed Kateri Tekakawitha Separate School, and three control sites (Stoney Creek, downtown Hamilton, and west mountain).

Data on the mutagenicity of urban air in various parts of the world generally show a range of less than one to ten revertants per cubic meter and all samples tested by Mutatech fell within this low range.[17] A maximum of 2.9 revertants per cubic meter was found at the southeast side of the landfill using TA98, which proved to be the most sensitive strain. Mutagenicity levels comparable to or greater than landfill samples were found at the control sites.

3.2 Leachate

Ames assays were also done on leachate samples collected from boreholes, a collection manhole on the landfill, locations upstream and downstream from the landfill on the Red Hill Creek and on Hamilton tap water.[18]

The results showed that in the case of leachate from only one borehole was a clear doubling of the background number of revertants obtained (with strain TA98), indicating unequivocally the presence of mutagens. Two other samples from another borehole and the Red Hill Creek downstream showed indications

that mutagenic material might be present but failed to produce a doubling of the background reversion rate.

The results show that some samples of leachate contain mutagenic chemicals. The levels, however, are low and near the limits of detection of the assay used. Given that the presence of polynuclear aromatic hydrocarbons (PAH's) in leachate was already known, this finding was not unexpected.

4. HYDROGEOLOGICAL INVESTIGATION

The hydrogeological research being done at the landfill by Dr. John Cherry and his associates from the Earth Sciences Department of the University of Waterloo, is the first major investigation to be undertaken in Canada on the movement of contaminated groundwater through fractured bedrock. Dr. Cherry and his team are also developing techniques for determining the attenuation of organics in sand and gravel. This work is being done in co-operation with Stanford University under the auspicies of the United States' Environmental Protection Agency, and the results will have application to the Upper Ottawa Street site.

The first stage of Dr. Cherry's work was the design and construction of a new groundwater sampling device. It was his opinion that an extensive investigation of the hydrology of the landfill would be prohibitively expensive if conventional monitoring devices were used. This is because the bedrock contains a complex network of lateral and vertical fractures through which contaminants migrate from the landfill and, therefore, sampling at various depths in vertical boreholes is required. Conventional monitoring devices are only able to sample one depth for each borehole; consequently, the drilling costs for many boreholes becomes expensive. To overcome this problem, Dr. Cherry designed a multilevel monitoring device consisting of a bundle of tubes in a PVC casing, which isolate discrete depth intervals in a single borehole.[19] As a result, a number of groundwater zones can be monitored within a single borehole.

In 1981, this multilevel device was installed in the bedrock at a site near the landfill and it performed successfully. Dr. Cherry then developed a proposal for a comprehensive two year investigation of the landfill.[20]

The first year of the study (1982) was planned for drilling and installing a network of multilevel monitoring devices. Inorganic chemical analysis of groundwater samples was done by the Ministry of the Environment and organic analyses by the University of Waterloo, Mann Testing Laboratories and Stanford University. This work was intended to provide information on the geology and patterns of contamination in the groundwater system. Interpretations of direction of groundwater flow and preliminary estimates of the amounts of groundwater flow in the main zones of contamination were sought.

Preliminary results have been obtained from work completed in 1982.[21] Twenty multilevel monitoring devices, each containing five or six piezometers, were installed in separate boreholes around the landfill to depths of between 70 and 150 feet. The locations of the multilevel sampling devices are shown in Figure 2. Most of these boreholes are situated around the periphery of the landfill and to the east, in the direction of expected contaminant migration. A few of the boreholes are at locations where contaminant migration is not expected but where its presence or absence should be established, for example, to the west of the landfill. Prior to the installation of this monitoring network, Gartner Lee Associates had installed 12 monitoring wells for the Regional Municipality of Hamilton-Wentworth, which are shown in Figure 3.

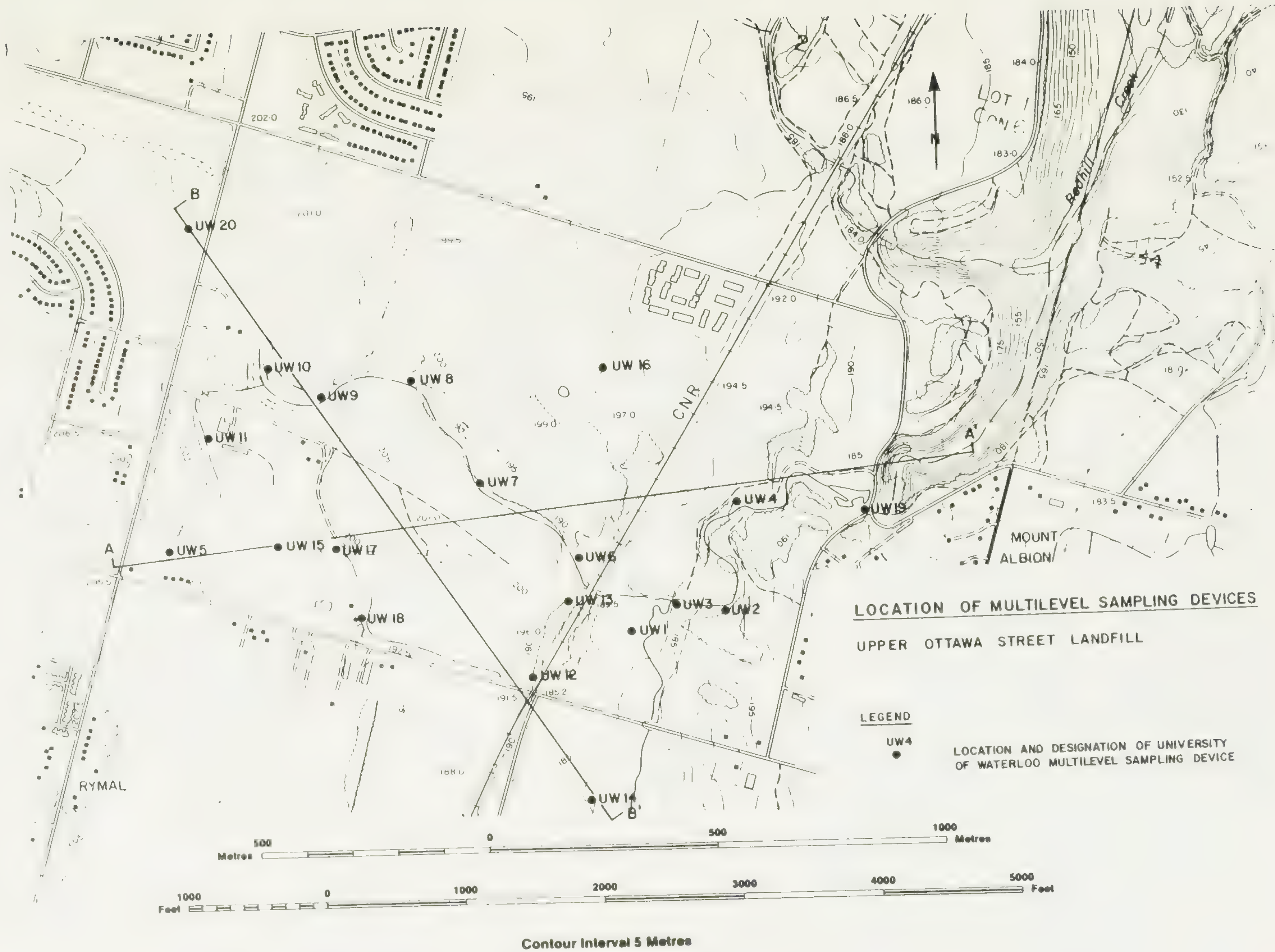
LOCATION OF MULTILEVEL SAMPLING DEVICES
UPPER OTTAWA STREET LANDFILL
LEGEND
UW4
LOCATION AND DESIGNATION OF UNIVERSITY OF WATERLOO MULTILEVEL SAMPLING DEVICE
MOUNT ALBION
RYMAL
CNR
Redhill Creek
UW 20
UW 10
UW 8
UW 16
UW 9
UW 11
UW 7
UW 4
UW 19
UW 5
UW 15
UW 17
UW 6
UW 13
UW 3
UW 2
UW 1
UW 18
UW 12
UW 14
A
A'
B
B'
Metres 500 0 500 1000 Metres
Feet 1000 0 1000 2000 3000 4000 5000 Feet
Contour Interval 5 Metres

FIGURE 2

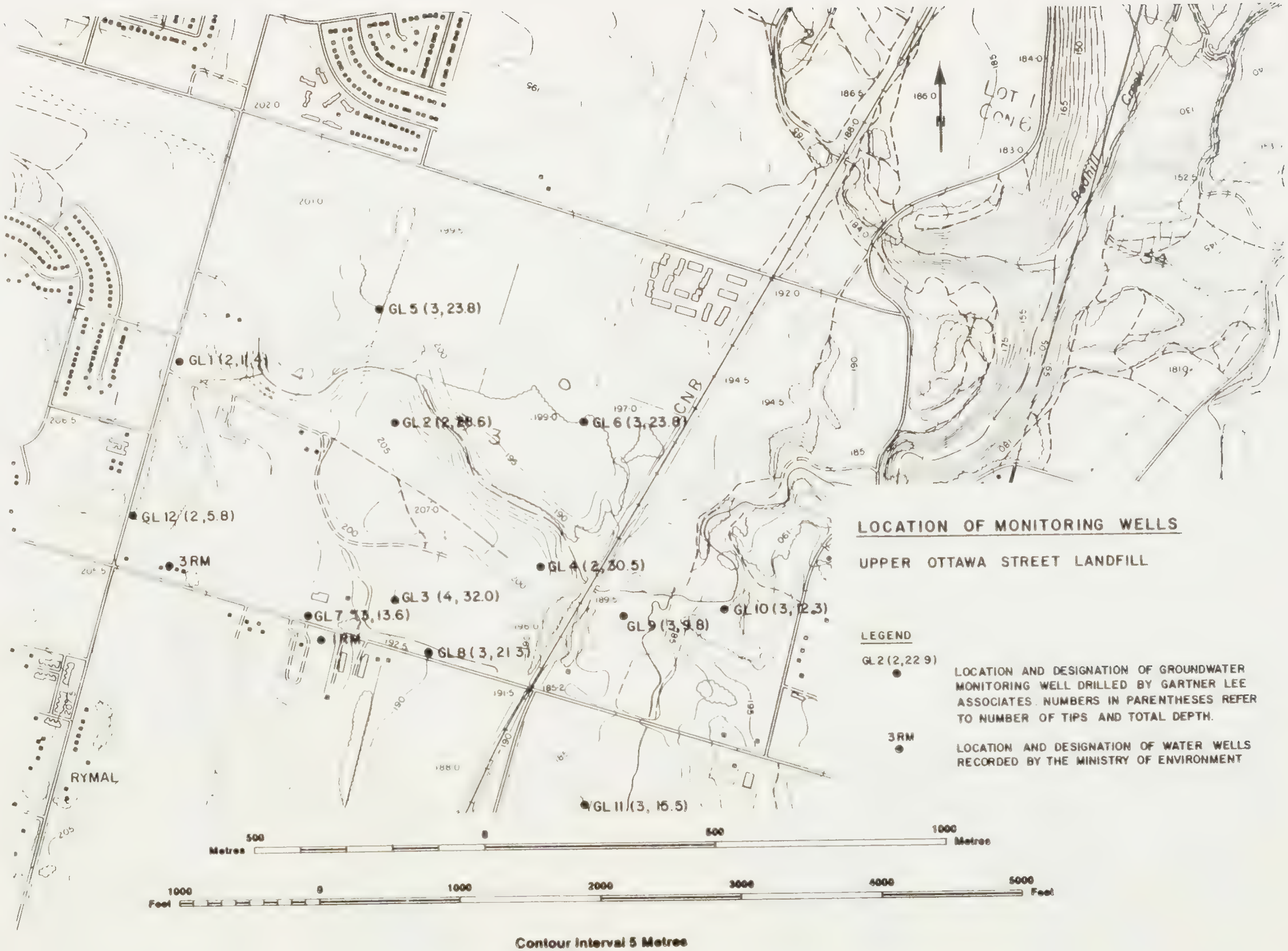
LOCATION OF MONITORING WELLS
UPPER OTTAWA STREET LANDFILL
LEGEND
GL 2 (2,22.9)
LOCATION AND DESIGNATION OF GROUNDWATER MONITORING WELL DRILLED BY GARTNER LEE ASSOCIATES. NUMBERS IN PARENTHESES REFER TO NUMBER OF TIPS AND TOTAL DEPTH.
3RM
LOCATION AND DESIGNATION OF WATER WELLS RECORDED BY THE MINISTRY OF ENVIRONMENT
GL 5 (3, 23.8)
GL 1 (2, 11.4)
GL 2 (2, 28.6)
GL 6 (3, 23.8)
GL 12 (2, 5.8)
3RM
GL 4 (2, 30.5)
GL 3 (4, 32.0)
GL 7 (3, 13.6)
1RM
GL 8 (3, 21.3)
GL 9 (3, 9.8)
GL 10 (3, 12.3)
GL 11 (3, 15.5)
CNR
RYMAL
LOT 1
CON 6
Redhill Creek
Metres
Feet
Contour Interval 5 Metres

FIGURE 3

The Upper Ottawa Street landfill is situated on dolomite and shale bedrock in which groundwater flows through fractures. The water table in the landfill is higher than the water table in the surrounding terrain and, therefore, leachate from the landfill must move downward into the fractured bedrock. This condition of mounded water table and downward leachate movement is typical of landfills in southern Ontario.

The rock cores and water level response tests in the multilevel monitoring devices indicate that the bedrock itself is slightly to highly permeable. The differences in water levels in the monitoring devices indicate that in much of the study area there is a downward hydraulic gradient. Because the shallow groundwater zone has a higher permeability, the dominant direction of flow is horizontal, along the bedding planes in the rock, away from the landfill towards Albion Falls.

Although the fractured dolomite and shale at the landfill are not as permeable as the sand and gravel hydrogeologic systems found at other sites, they are sufficiently permeable for contaminants to be transported horizontally by groundwater flow at rates reaching hundreds of yards per year. The transport rates of contaminants in many parts of the study area probably range from 10 to 100 yards per year. Initial groundwater sampling indicates that contaminated groundwater extends at least 1,600 feet to the east of the landfill site.

Beneath the landfill, leachate can move downward through vertical fractures (i.e., joints in the rock) but the extent of vertical leachate migration is not yet

known. There are, however, many more horizontal than vertical fractures due to the nature of the rock and, therefore, a greater potential for contaminants to move horizontally.

Concentrations of chloride and of total dissolved organic carbon (TOC) have been measured in nearly all of the piezometers in the multilevel devices as preliminary means of determining the chemical status of the water. Differences of more than a factor of 10 for each of these parameters commonly occur within each multilevel device. The detected concentrations of chloride (ranging from roughly 200 parts per million up to 100,000 parts per million) and TOC (ranging from roughly 10 parts per million to 2,000 parts per million) are moderately to extremely high compared to other landfills, where concentrations of chloride and TOC of more than 20 parts per million indicate leachate contamination. At the Upper Ottawa Street landfill, however, these parameters are not conclusive indicators of leachate contamination because uncontaminated groundwater in the shale and shaly limestone in the area was shown to have high levels of these constituents, derived naturally from the rock.

Groundwater located away from the contamination zone of the landfill was found to contain concentrations of chloride, iron, manganese, and sulphate in excess of Ministry of Environment's water quality standards for public services water. In addition, groundwater contaminated by the landfill contained concentrations of sodium, calcium, several forms of nitrogen (but not nitrate), boron and lead in excess of MOE standards.

Analyses of specific organic constitutents in groundwater is underway but preliminary results indicate an absence of volatile chlorinated compounds in contaminated groundwater. These solvents are among the most common organic environmental contaminants encountered in other landfills. Very low levels (less than 10 parts per billion) of hydrocarbon-like contaminants are present. The bulk of the dissolved organic constituents appears to be high molecular weight molecules commonly produced by the natural breakdown of organic material deposited in landfill sites.

In 1983, it is likely that many more multilevel monitoring devices will be installed in areas where specific problems were identified in 1982. The emphasis on work carried out in 1983 will be almost entirely on contaminant occurrence in the groundwater and the rock. If the leachate contaminants in the groundwater are adsorbed on the surfaces of the fractures these substances could be expected to re-enter the flowing groundwater at a later date and present future problems. This will be one of the important questions addressed in the second stage of investigation.

Residents in the immediate vicinity of the landfill are served by city water and do not depend upon wells. However, if the groundwater is discharging or does eventually discharge to the surface, for example, in Albion Falls park beside the landfill, in residential neighbourhoods, or into Red Hill Creek, persons might be exposed to landfill contaminants. Additionally, a potentially serious environmental threat could exist if highly contaminated groundwater discharges through the face of the escarpment.

The network of multilevel borehole devices installed around the landfill will act as a permanent monitoring system for the future. It will be possible to monitor groundwater for early changes in the type or concentrations of toxic compounds coming out of the landfill.

Unfortunately, at the present time there are few effective cleanup measures for removing contaminants from groundwater. The single most feasible method for addressing the problem is to ensure that the landfill has a secure cover that will reduce the entry of water to a very low rate. If the cover is effective in preventing infiltration, the mounding of the water table will be reduced so that it is below the bottom of the refuse. Contamination of groundwater by the landfill will then be greatly reduced and over many years the system will undergo a decline in total contaminant load and concentrations. Therefore, Dr. Cherry's work can be used as a base for assessing the effectiveness of landfill control measures and for studying future trends in groundwater contamination.

5. MISCELLANEOUS STUDIES

The Committee has undertaken research in four additional areas: geophysical surveys, examination of animals, aspects of the landfill cover, and a survey of absentee rates due to illness for children attending a neighbourhood school.

5.1 Geophysical Studies

The Committee attempted to address the suggestion that the landfill may be a 'time bomb'. Specifically, are there barrels of hazardous wastes buried in the dump that will one day corrode and release their contents into the landfill and the outside environment?

The Committee received conflicting information about the number of intact barrels that might be buried in the landfill. Some reports suggested that barrels were stacked in piles and covered carefully. Others claimed that most barrels were crushed by bulldozers at the working face of the dump.

Waterloo Geophysics Ltd. was asked to determine if geophysical techniques could be used to detect steel barrels within the landfill and if geophysical methods could locate concentrations of toxic wastes (other than those in barrels) within the landfill mound. The company carried out preliminary investigations employing three types of tests: ground-imaging radar, magnetometers, and electromagnetic detectors.[22]

Ground-imaging radar was demonstrated to have potential for locating barrels only at a depth of less than 10 feet - too limited a penetration to be useful. Magnetometer instruments also did not provide useful information because of the impossibility of distinguishing between barrels and other metal objects such as car bodies. Electromagnetic techniques, including an EM-15 metal detector and EM-31 and EM-16R conductivity instruments, were tried but also failed to provide information because of shallow penetration capability and the uniform conductivity/ contamination levels over the landfill. The overall results of this study suggest that geophysical techniques are unlikely to provide an answer to the question of whether barrels are buried in the landfill.

5.2 Small-Animal Study

The Committee undertook a small-animal study for the purpose of obtaining information on whether the health of animals exposed to the landfill has been affected and if tissue residue analysis might identify chemicals in the landfill that were not being detected in the other analytical work. This study was intended to provide clues for the health studies of workers and residents. The limitation of this study, the small number of animals and the lack of knowledge concerning the exposure of the animals to other possible sources of pollution, were recognized.

Two racoons, two squirrels and one rabbit were trapped on or near the landfill. A gross necropsy and histopathology examination of the animals was done at the Ontario Veterinary College, University of Guelph.

No abnormalities or other findings of significance were observed. Tissue residues were analyzed at the Pesticide Residue Laboratory in Guelph and it was concluded that the trace amounts of chemicals detected in the samples are characteristic of background levels normally found in animal tissues. This suggests that these animals did not come into direct contact with signficant amounts of toxic chemicals from the landfill.[23]

5.3 Landfill Cover

The Committee is concerned with the effectiveness of the landfill cover in terms of its ability to prevent further infiltration of water through the garbage mound (thereby decreasing the production of leachate). There appear to be no criteria for designing landfill covers other than some general guidelines to the effect that the cover material should be as thick and impermeable to water as possible. Clay has been found to be an effective cover. It is accepted that a top cover of soil and grass is necessary to protect the clay from drying and cracking and to promote evaporation of water. Research is being done in the United States on synthetic cover materials.

The Upper Ottawa Street Landfill is now covered with a thick layer of steel industry wastes and a thin top layer material consisting largely of clay. Grass seeding has been attempted several times, but has not yet been successful. The sides of the landfill are extremely steep, which promotes development of deep erosion cracks in the clay as precipitation runs off the mound.

This is a particular concern on the north side of the landfill, which impinges directly on the Red Hill Creek. An erosion prevention wall, approximately 10 feet high, now separates the base of the landfill from the creek.

A system of pipes has been installed around the other three sides of the landfill to collect leachate. The leachate then flows by gravity or is pumped upgradient into a sanitary sewer, which leads to the city sewage treatment plant. The Committee's concern about leachate exiting the landfill into the sanitary sewer was referred to earlier in the context of future analytical work on leachate. The volume of leachate being collected will provide some indication of how effectively the cover is working to prevent entry of water over time. For these reasons, the Committee requested the Region to install an elapsed time meter on the pump well, and flow meters on the pipe through which leachate flows downgradient into the sewer. The time meter on the pump has been installed and work is expected to begin shortly on installing the flow meters. These installations, in conjunction with seasonal sampling and analysis, will provide information on the volume and composition of leachate moving from the landfill into the sanitary sewer. If the cover is secure, leachate generation and migration will gradually decrease.

A further area of concern relates to the nature of the cover which was placed over the site following closure. In excess of two million tons of steel industry wastes, including foundry sand, slag fines, steelmaking oxides and inert fill, were installed as an intermediate cover ranging up to a thickness of 20 feet on the top of the landfill. Unanswered is the question

of whether this cover is sufficiently impermeable to prevent, or to greatly minimize, the infiltration of water into the landfill and thus to reduce future contamination of groundwater. Another important consideration may be the presence in this material of toxic substances such as phenol, PAH's and other organic compounds, which could be leaching out and causing air and water contamination. The Committee is examining this matter.

The Committee has consulted with experts in Canada and the United States on the matter of the cover and is engaging in ongoing discussions with the Regional Government concerning improvements that could be made.

5.4 School Absenteeism

A particularly sensitive concern to area residents is the close proximity of schools to the landfill. Concerns have been expressed to the Committee about the safety of children attending school across the street from the landfill. The Committee decided that one way of addressing this issue was to investigate whether children attending Blessed Kateri Tekakawitha Separate School were absent from school more often because of illness than were children attending two schools on the west mountain and in Stoney Creek. These two schools were selected for comparison because of similar student population size, age of school and similar neighbourhoods in which the schools are located.

With the permission of the Hamilton-Wentworth Roman Catholic Separate School Board, the study was carried out by researchers who reviewed student attendance records at the three schools for kindergarten through grade eight for the years 1978 to 1981 inclusive. The data were tabulated by computer and the results are calculated as a ratio of illness days to term days. This ratio provides a standardized measure of absence.

	1978	1979	1980	1981	1978-80 Average
West Mountain	.0573	.0456	.0394	.0439	.0466
Blessed Kateri	.0425	.0421	.0390	.0451	.0421
Stoney Creek	.0382	.0333	.0364	.0353	.0385

These results indicate that there is little difference among average absenteeism rates for students attending these three schools. The west mountain school appears to have the highest rate of absenteeism, followed by Blessed Kateri and then the school in Stoney Creek.

6. TOXICOLOGICAL WORK

Toxicological information on many of the compounds detected in the landfill is limited. This can be understood when one considers that a thorough toxicity study of a single compound requires two years of work and costs over $500,000. It is clearly beyond the purview of this study to generate new toxicity information about compounds detected in the landfill and we must, therefore, rely on information available in the scientific literature.

In addition to the lack of basic toxicity information on many compounds, the Upper Ottawa Street Landfill Study is confronted with other problems. The first is that little is known about the effects of multiple exposure or toxicological interactions of chemicals. This is a serious issue for landfill studies where complex mixtures of chemicals are encountered. A second issue relates to the relevance of permissible exposures. For most of the compounds encountered, environmental standards have not yet been established. On the other hand, threshold limit values, which represent the assumed maximum 'safe' permitted exposures for workers to chemicals during an eight hour working day or 40 hour working week, have been set for many industrial chemicals. However, persons living near landfill sites or other sources of pollution generally experience lower levels of exposure over longer periods of time as contrasted to maximum permitted exposures for workers. Additionally, workers are usually healthy individuals whereas the general population contains the young, the infirm, and the elderly, who may be more sensitive to the effects of exposure. A third complication arises when a landfill has been shown to

contain toxic substances, particularly carcinogens, but the actual current exposure of residents is no higher than that frequently found in an urban environment.

The Committee initiated toxicological work with two objectives in mind: first, to give guidance to and limit the scope of chemical work, and second, to provide direction to the health studies. The role of the toxicology consultants has been to select a list of compounds of toxicological concern from the large number of chemicals detected in the qualitative surveys.

The identities of these 'priority pollutants' were then to be confirmed and the compounds quantified. Our experience has shown this to be a massive undertaking because of the sheer number of compounds that require some toxicity assessment in order to sort out toxic substances from the non-toxic chemicals detected. Another major problem was associated with the limitations in the analytical techniques themselves. As noted above, a great deal of time and effort was spent on toxicity assessment of the many 'worst case possibilities' identified in Sciex's first air survey but, as it turned out, in only a few of the cases were the 'worst case' assignments correct.

The Committee planned for detailed toxicity profiles to be developed by its consultant for each of the priority toxic substances identified from the analytical work.[24] It was initially thought that detailed assessments were required in order for the health studies to be designed in such a way as to relate questions contained in the questionnaire on health effects to specific compounds to which residents and workers may have been exposed.

The development of these profiles required the toxicologist consultant to compile toxicity information from many sources, to assess the quality of the data and to make a judgement on its relevence and implications for landfill exposure. This proved to be an extremely onerous task.

As this work was proceeding, it became clear to the Committee that the computerized toxicological data bases in the United States are more advanced than those in Canada. There are private consulting companies in the United States that specialize in toxicity evaluation. These companies have automated data bases and extensive files (including published and unpublished studies) on thousands of chemicals, which can quickly be assembled into a comprehensive dossier of literature on these chemicals.

In light of this, the Committee decided that it would be sufficient for the purposes of the health studies to obtain less elaborate assessments on the toxic properties of certain of the chemicals.

The Committee decided to have this work done by Environ, a health and environmental science consulting firm located in Washington, D.C. Environ designed the report to identify the various types of toxic injury or disease that are associated in the literature with exposure to specified levels of chemicals and identified exposure pathways. The chemicals that were studied in this report include those compounds present in the vicinity of the landfill whose identities have been confirmed in the analytical work and other compounds for which only tentative identification is available.

The report was prepared in tabular form presenting data on target organ toxicity and toxic disease for each of the selected compounds. This report provides sufficient information to guide the planned health studies.[25]

7. HEALTH STUDIES

People who live and work near the landfill see a most critical aspect of the Committee's investigation to be the health studies. The community wants information on whether the landfill affected the health of persons in the past, whether current levels of exposure pose a health threat and whether health problems will develop in the future because of exposure to chemicals in the landfill.

In addition to the difficulties involved in relating toxicological assessments to the health risks associated with chemical exposure, other problems must be considered in the design of health studies of this nature. For example, the landfill was closed before the health study began. It is not possible to assess the levels of exposure in past years but it is reasonable to assume that they were higher when the landfill was operating than they are today. Only a small number of residents have lived in the area for a long period of time. The majority of the residents moved into the area after 1976, which is considered too short a period of time for chronic health effects of chemical exposure to develop to the stage where they would be detectable. Finally, workers and residents are exposed to chemicals in their homes and other workplaces and it may be difficult to separate these confounding exposures from the effects of exposure to the landfill.

The Committee's work on health studies has involved the following phases: first, commissioning a feasibility study, second, designing a workers' health study to be carried out under the Committee's direction and, third, designing a residents' health study. The residents' health study will be carried out by the group that is awarded the contract through a bidding process.

The feasibility study for an epidemiological investigation was submitted to the Committee in April, 1982.[26] The Committee sent the proposed study to three external referees for review. In light of the reviewers' comments and the Committee's own reservations about the approach, a decision was made not to implement its recommendations.

The Committee perceived several major problems with the study proposal: it was not designed to examine directly the physical health of residents and workers; the sequential nature of the study left open the possibility that a complete health survey of residents might not be undertaken; and too much emphasis was placed on the ability of the analytical chemistry studies to demonstrate hazard and, therefore, to justify a comprehensive health study.

The Committee then retained Dr. Joseph Highland, a biochemist currently involved in a hazardous waste research program for the Centre of Energy and Environmental Studies at Princeton University and a principal in Environ, to advise in the design of the health studies. It was decided that separate studies would be done on the health of landfill workers and of residents.

The Committee's strategic objective for doing a workers' study is to generate hypotheses regarding possible health effects from exposure to the landfill, which can be tested in a subsequent larger scale study of residents. The workers represent a potentially high dose exposure subgroup and could, therefore, be a sensitive indicator of any potential health effects associated with exposure to chemicals in the landfill.

The workers' study is a questionnaire survey, the size of which has grown considerably from the forty or so workers identified in the feasibility study. Progress has been made in identifying persons who worked on and near the landfill so that the study population now numbers over 150 persons. The results of the workers' study are expected to be available by mid-1983. These results will then assist in the design of the residents' study.

Work has been proceeding on the design of the residents' study. A prequestionnaire has been designed to obtain demographic information on the resident population for use in identifying a control group for the study. The prequestionnaire will be administered by the Upper Ottawa Street Residents' Association.

Work is currently underway to obtain the names, addresses and length of residency for approximately 5,000 households located in the nine neighbourhoods surrounding the landfill. This information was taken from city tax assessment rolls and is being computerized. From this data base, the selection of residents for the study by length of residency and geographical proximity to the landfill, will be made.

The residents' study will be a questionnaire survey of persons with the highest potential for exposure to the landfill. Additionally, a control group from another area in Hamilton not situated near a landfill, but with similar demographic characteristics, will be used. The questionnaire for this study has been partially designed and will be completed once the results of the workers' study are known.

In addition to the questionnaire survey, medical examinations of a selected group of the residents by a family physician or specialist consultant may be undertaken. A questionnaire and recording form for use by the examining physician has been designed for this purpose.

Considerable work remains to be done in developing the details of the residents' study. The expectation is that field work on the residents' study will begin in the fall of this year.

s investigation it
awa Street landfill
ntially toxic
pear to be escaping
e in concentrations
to persons living
urhoods. Further-
by city water,
o the groundwater
There is, however,
ed groundwater
nd efforts must be
he landfill is
mation to a minimum.

ds (e.g., trichloro-
d dioxins) are the
ny landfills in the
United States, including the ... Canal site. Chemical analyses on core samples from the Upper Ottawa Street landfill have detected PCB's in low concentrations. These substances, however, do not appear to be migrating from the site.

Volatile toxic substances (e.g., toluene, 1,1,1-trichloroethane) are clearly migrating from the landfill in the escaping gas, much of which consists of methane generated by microbial decomposition of domestic garbage. Although current exposures to these substances are unlikely to pose a hazard to health, the Committee reiterates its conclusion that the landfill does contain a variety of toxic compounds.

Therefore, the Committee recommends to the Provincial and Regional Governments that an active landfill gas collection and flaring system be installed at the Upper Ottawa Street landfill and that the first phase of this work begin as soon as possible.

The Committee is in the process of carrying out a health study of landfill workers. This will be followed by a health study of residents. The Committee's final report will present the results of these studies and may also make further recommendations concerning containment of potentially toxic substances in the landfill. While these substances appear to be reasonably well- contained at the present time, careful and regular monitoring of the landfill will be required to ensure that any change in the present situation will be detected so that necessary remedial measures can be taken.

REFERENCES

1. Frank Crossley. The Effects of the Upper Ottawa Street Landfill Site on Groundwater and Surface Water. February, 1982. CA4ON HW Q90 83I56R1

2. Pohland, F. G., Gould, J. P., Ramsey, R. E. and Walters, D.C. The Behaviour of Heavy Metals During Landfill Disposal of Hazardous Wastes. IN: Schultz, D. W. (editor) Land Disposal of Hazardous Wastes: Proceedings of the Eighth Annual Research Symposium (Environmental Protection Agency Publication No. 600/ 9-82-002), March 1982. CA4ON HW Q90 83I56R2

3. Mann Testing Laboratories. Chemical Analysis of Core Samples from Boreholes # 2 and # 4. October, 1982. CA4ON HW Q90 83I56R3

4. Sciex. Report on Air Quality Surveys in the Upper Ottawa Street Landfill Site. February, 1982. CA4ON HW Q90 83I56R4

5. Sciex. Final Report on Air Quality Surveys on the Upper Ottawa Street Landfill Site. January, 1983. A4ON HW Q90 83I56R

6. The Registry of Toxic Effects of Chemical Substances (Microfiche edition). R. J. Tatken (editor). United States Department of Health and Human Services, Centres for Disease Control and National Institute for Occupational Health and Safety. Cincinnati, 1982.

7. Mann Testing Laboratories. Analysis of Pre- and Post-Flare Gases from the Test Well on the Upper Ottawa Street Landfill Site. December, 1982. ONHW Q90

8. Mann Testing Laboratories. Tenax Sorbent Tube GC/MS Analysis of Air on and Around the Upper Ottawa Street Landfill Site. December, 1982. CA3ONHWQ90 83156R8

9. Conestoga-Rovers & Associates Limited. Feasibility Study of Landfill Gas Control at the Upper Ottawa Street Landfill. March 1983. CA3ONHWQ90 83156R9

10. Mann Testing Laboratories. Chemical Analysis of Pre- and Post-Flare Gases, January, 1983. CA3ONHWQ90 83156R10

11. Mann Testing Laboratories. Quantification of Selected Volatile Organics at the Upper Ottawa Street Landfill Site. February, 1983. CA3ONHWQ90 83156R11

12. Mann Testing Laboratories. Reports of Chemical Characterization by GC-MS Spectrometry. May and August, 1982. CA3ONHWQ90 83156R12

13. Ryan, J. J. Correspondence RE: Analysis of Two Leachate Samples for Dioxins and Furans, Health Protection Branch, Health and Welfare Canada. May 1983. CA3ONHWQ90 83156R13

14. Ministry of the Environment. The Effects of the Upper Ottawa Street Landfill on Red Hill Creek. November, 1978. CA3ONHWQ90 83156R14

15. Mutatech Inc. Report on Ames Tests on Gases Emanating from Vents in the Upper Ottawa Street Landfill Site. September, 1982. CA3ONHWQ90 83156R15

16. Mutatech Inc. Report on the Analysis of Air Particulates CA3ONHWQ90
and Leachates from the Upper Ottawa Street Landfill for 83Y56R16
Mutagencity in the Ames Tests. November, 1982.

17. Commoner, B., Madyastha, P., Brownsdon, A. and Vitayathil, A. J. (1978) Environmental Mutagens in Urban Air Particulates. J. Toxicol. Environ. Health 4, 59-77.

Moller, M., and Alsheim, I. (1980) Mutagenicity and PAH-Analysis of Airborne Particulate Matter, Atmos. Environ. 14,83-88.

Wang, C. Y., Lee, M., King, C. M. and Warner, P. (1980) Evidence for Nitroaromatics as Direct-Acting Mutagens of Airborne Particulates. Chemosphere 9, 83-87.

18. Mutatech Inc. Report on the Analysis of Air Particulates (see 16)
and Leachates from the Upper Ottawa Street Landfill for Mutagenicity in the Ames Test. November, 1982.

19. John Cherry. A Multilevel Device for Groundwater CA3ONHWQ90
Sampling and Water Level Monitoring in Fractured Rock. 83Y56R19
February, 1982.

20. John Cherry. Proposal for an Investigation of Ground- CA3ONHWQ90
water Contamination at the Upper Ottawa Street 83Y56R20
Landfill Site. April, 1982.

21. John Cherry. Hydrogeological Investigation of the Upper CA3ONHWQ90
Ottawa Street Landfill Site: A Progress Report for 83Y56R21
the Period April, 1982 through February, 1983.

22. Waterloo Geophysics Inc. A Preliminary Geophysical Study at the Upper Ottawa Street Landfill Site. September 1982. CA3ONHWQ90 83I56R22

23. I. K. Barker. Reports on Pathology and Pesticide Residue Analysis of Animals Trapped on and Near the Upper Ottawa Street Landfill. December, 1982. CA3ONHWQ90 83I56R23

24. Robert Willes. Toxicity Profiles for Selected Compounds. November, 1982 to June, 1983. CA3ONHWQ90 83I56R24

25. Environ Corporation. Preliminary Summary of the Inherent Toxic Properties of Selected Substances Identified at the Upper Ottawa Street Landfill Site. January, 1983. CA3ONHWQ90 83I56R25

26. Andrew Harper. Final Report on the Feasibility Study. April, 1982. CA3ONHWQ90 83I56R26

COPIES OF THE REPORTS LISTED ABOVE ARE AVAILABLE ON REQUEST. THERE WILL BE A SMALL PHOTOCOPYING CHARGE DUE TO THE VOLUME OF THIS MATERIAL.